ANNALS
OF
OTOLOGY, RHINOLOGY
AND
LARYNGOLOGY

VOL. 44. SEPTEMBER, 1935. No. 3.

LXI.

OSSIFICATION OF THE CARTILAGES OF THE LARYNX AND ITS RELATIONSHIP TO SOME TYPES OF LARYNGEAL DISEASE.*

H. MARSHALL TAYLOR, M. D.,

JACKSONVILLE, FLA.

Nearly a century ago, in an address before the French Academy of Sciences, Segond[1] discussed the ossification of the cartilages of the larynx. He stated that Columbus, the pupil and successor of Vesalius, found these cartilages frequently ossified in persons advanced in years and considered age the chief cause of this change. Other early anatomists also made mention of the ossification of the laryngeal cartilages with increasing age. Segond,[1] Schottelius,[2] Chievitz[3] and other writers of the nineteenth century recognized the wide variability of the age period at which ossification of these cartilages occurs, and distinguished between the pathologic process and the process which is to a certain extent normal and in the development of which senile change has for centuries been regarded as the sole causative agent.

Segond[1] felt that individual "dispositions" and certain morbid conditions were undoubtedly factors in determining the course and the extent of the osseous change. In 1879, Schottelius[2] stated that normal calcification of the laryngeal cartilages results from the increasing vascularity of the larynx following puberty, that vascularity

*Presented before the annual meeting of the American Laryngological Association, Toronto, May 30, 1935.

MEDICAL LIBRARY

of these cartilages is pathologically increased in chronic inflammatory processes, and that calcification may, therefore, occur prematurely and extend more rapidly than normally. In the normal process, he observed, the calcified cartilage is a pale yellow in color and is dry; when abnormal calcification is present, it is reddened and unduly rigid. Retterer,[4] forty years later, stated that this reddening represents a process of vascularization and calcification which precedes true ossification. In the dog, he found the process essentially the same as in man. He regarded the formation of bone in the cartilaginous tissue of the larynx a normal development rather than a senile regression and was of the opinion that the change takes place by a process quite different from that in growing bones.

Segond,[1] Thost[5] and others were of the opinion that singing is a causative factor in hastening the process of ossification since as a rule the initial processes are found at the points of insertion of the ligaments or muscles in the laryngeal cartilages. In a recent article Terracol[6] stated that roentgen studies of the larynx in professional singers and in nonsingers show no difference in the extent and degree of calcification of the laryngeal cartilages. Nevertheless, on theoretical grounds he, too, was of the opinion that the advancing calcification and ossification of these cartilages affects the voice, especially the singing voice.

The consensus of opinion as to the age factor is that, in general, the ossification of the laryngeal cartilages advances with age; so great, however, is the variability of the age period that it is impossible to determine the age of persons from the degree of ossification of these cartilages. Segond[1] found that after the age of sixty years usually there is definite ossification and at seventy the process may be completed, but in some persons of eighty years of age ossification is only slight and limited to certain areas. In 1866, Hunt[7] observed a man 103 years of age whose larynx postmortem showed not even beginning ossification. Two decades later, Meunier[8] presented to the Anatomical Society of Paris a specimen of abnormal ossification of the hyoid bone from a man sixty-four years of age in which the thyroid and the cricoid cartilages were completely ossified and the arytenoid cartilage nearly so. Schottelius[2] concluded from his observations that the process begins soon after the age of twenty in normal healthy persons.

In 1882, Chievitz[3] reported a study of the ossification of the laryngeal cartilages in 232 anatomic specimens, 127 from men and 105 from women. The earliest age period at which ossification was found in the individual cartilages was the twentieth year for the

thyroid and cricoid cartilages in both sexes, the middle twenties for the arytenoids in men, and between twenty and thirty in women. Chamberlin and Young[9] stated in a recent (April, 1935) article that all of the original work pertaining to the age factor has resulted in the conclusion that actual bone formation takes place before full maturity is reached and they mentioned Chievitz[3] put it exceptionally well when he said that ossification begins normally when skeletal growth is otherwise complete.

In specimens from boys fourteen and fifteen years of age, Dreyfuss,[10] in 1916, observed crepitation on puncture with a needle and roughness of the cut surface in the cricoid cartilage. After the age of fifty years the process in men is well advanced and at the age of seventy the entire cartilage is usually completely ossified, he noted. In the thyroid cartilage the process begins in the male in puberty, he observed, and at about the same time as in the cricoid cartilage. He found partial ossification of the inferior cornu in a boy at the age of fourteen and stated that after the age of forty the ossification of the alæ is almost complete in men. In the arytenoid cartilage, also, he observed that the process begins at puberty in males but about two years later than in the cricoid cartilage; it progresses much more slowly than in the cricoid cartilage, however, and is complete only at an advanced age. He concluded that in all three cartilages the process is more gradual and less extensive at all ages in women than in men.

Dissection of the larynx from several subjects, eighty to ninety years of age, reported by Segond,[1] showed complete ossification in these three cartilages, but in the epiglottis, the corniculate and the cuneiform cartilage there was no evidence of osseous change. Dreyfuss[10] stated that he had never found bone formation in a normal epiglottis, and Gardner[11] recently observed that "the epiglottis, the cuneiform cartilage and the apexes of the arytenoid cartilages are composed of yellow elastic tissue and show little if any tendency to calcification."

Pathologic processes of ossification, according to Dreyfuss,[10] may be found in the larynx in three forms: (1) ossification in cartilage tumors of the larynx; (2) excessive bone formation in the form of exostoses or bone plates formed in cartilage rests in the mucosa; and (3) premature and excessive bone formation in the laryngeal cartilages in chronic infectious processes.

The earlier anatomic writers were of the opinion that ossification begins first in the cricoid, next in the thyroid and last in the arytenoid

Fig. 1. A roentgenogram of the larynx of a woman of 55 years. The thyroid cartilage shows marked ossification except at the round or oval windows which represent remaining cartilage. The superior and inferior cornua also shows ossification.

cartilage, although some of them concluded, as did Chievitz,[3] that in the cricoid and thyroid cartilages this change begins at approximately the same time. This author described in detail the advances of the process and stated that in no instance did he find evidence of bone formation in the arytenoid cartilage if none was present in the thyroid and cricoid cartilages. In the thyroid cartilage, he noted, the process progresses differently in the two sexes, and in the cricoid cartilage the median portion of the ring rarely shows ossification in women.

Agreeing with Chievitz[3] in most particulars, Bergeat[12] noted that the initial processes are found at the points of insertion of ligaments or muscles in the laryngeal cartilages. Segond,[1] fifty years earlier, reported that ossification begins in the cricoid cartilage at the point of insertion of the cricothyroid muscle in the thyroid cartilage in the posterior border of the alæ, and in the arytenoid cartilage at the base, extending outward to the points of insertion of the cricothyroid muscles. In both sexes, Dreyfuss[10] found, the osseous change in the thyroid cartilage begins in the inferior cornu, and almost at the same time in the superior cornu, extending from these points along the posterior border of the alæ and then forward along their lower border. In the specimens which Kofler[13] studied, calcification and ossification were most marked at the periphery of the cartilages; toward the center of the cartilage the bone tissue was less in extent, but there were large marrow spaces fairly well vascularized and filled with fatty marrow as in normal spongy bone elsewhere. Some specimens showed rarefaction of the bone and serous atrophy of the fatty marrow.

To a great extent the findings of the roentgenologists are in accord with the conclusions of the anatomists. Both groups are agreed that ossification of the laryngeal cartilages advances with age, although it is impossible to determine the age of persons from the degree of ossification of these cartilages. Roentgenologists have found, however, that in general the process occurs in the thyroid earlier than in the cricoid cartilage.

As early as 1896, Scheier[11] pointed out the value of a roentgen examination of the larynx as a means of studying the process of ossification in the cartilages. He was evidently the first to use the roentgen ray to determine the extent and variety of sites of bone formation. Two years later, he reported a roentgen study of the larynx in seventy cadavers of both sexes and stated that his findings were in accord with his study of anatomic specimens from Virchow's collection. With the roentgen equipment and technic available at

that time he was unable to obtain roentgenograms of the larynx in the living that demonstrated the ossification of the cartilages clearly and definitely, but in an article published in 1901 he noted that such roentgenograms may show ossification of the laryngeal cartilages and may offer a means of studying this process in the living. In this article he reported roentgen studies of anatomic specimens of the larynx from sixty-five men and fifty-five women, which confirmed the conclusions of his study of 1898, especially in regard to differences of sex. As did Chievitz,[3] he noted that in the thyroid cartilage following ossification of the posterior border, the process advances differently in the two sexes, and he concluded that complete ossification of this cartilage is unusual in women. He also observed that the entire posterior portion of the cricoid cartilage may become ossified, but the anterior portion is rarely completely transformed into bone, especially in women. Although the first centers in the arytenoid cartilage are at the base, in one woman, thirty-seven years of age, he found that the process began at the upper point of the pyramid. He stated that this cartilage may undergo complete ossification after the age of forty-five years.

This author concluded that the thyroid cartilage first shows osseous change, the cricoid next and the arytenoid last. In his specimens he found that all of the laryngeal cartilages had undergone complete ossification in several men, but never in a woman. Two years after Fraenkel,[15] in 1908, reported that he found no differences of sex in the development of ossification other than that the process begins somewhat earlier in women than in men, Sheier[14] confirmed his original findings by a special study of specimens, chiefly from women. In one specimen from a woman, 102 years of age, he found the degree of ossification not much further advanced than is usual in women thirty to forty years of age, and in another from a woman 101 years of age the anterior half of the thyroid cartilage remained cartilaginous. Although in one man fifty-eight years of age the ossification of the laryngeal cartilages was no further advanced than in another man of twenty-five, and in one woman seventy-five years of age it showed the same degree of ossification of the thyroid cartilage as in another woman of twenty-one years, in general, Sheier[14] concluded, the process advances with age.

Because of the wide variability in the rapidity and degree of change, Thost,[5] in 1913, likened the process of ossification to the graying of the hair. In his roentgen study of the larynx in 261 persons in whom previous laryngoscopic examination had shown the larynx to be normal, he demonstrated the advantages of roentgeno-

grams over the laryngoscope in studying the structure of the laryngeal cartilages and the process of ossification in these cartilages. The next year Weingärtner[16] showed roentgenologically in living subjects the progressive stages of bone formation typical of the normal larynx, and six years later, Ceresole[17] stressed the importance of correct interpretation of areas of ossification, especially in the anterior portion of the thyroid cartilage where the process is best shown in lateral roentgenograms. This author studied the lateral roentgenograms of the larynx in 3,708 patients, from twenty to fifty-two years of age, at the military hospital in Vienna, and in the majority of younger men who showed ossification in the anterior portion of this cartilage he observed that some chronic disease was present—chiefly syphilis and tuberculosis, though not laryngeal tuberculosis. Several had chronic arthritis.

Wulfson and Ginsburg[18] stated in 1930 that the laryngeal cartilages are not visible in the roentgenogram until the beginning calcification and progressive ossification, which follow the attainment of sexual maturity, render them so. These authors described the difference in the development of the process in the thyroid cartilage in the two sexes which Chievitz[2] and Sheier[14] noted. They found that, having advanced upward from the region of the inferior cornu along the posterior border in both sexes, it develops in men after about the age of thirty, from the cornua forward along the borders until the areas of bony tissue meet and thus form round or oval areas or windows of cartilage which become progressively smaller until the whole cartilage may undergo complete ossification, while in women it advances through the entire width or may take place by degrees in various areas. They stated that at the age of fifty to sixty years both the shape and the structure of the bony tissue of this cartilage are usually shown in the roentgenogram, but they concluded that the extent of the process does not depend so much on age as has been supposed, for extensive ossification may occur in young persons and, on the other hand, only a limited degree in older persons. In the cricoid cartilage the process advances from the upper lateral border and the region of articulation with the thyroid cartilage, they observed, the border adjacent to the thyroid cartilage showing ossification before that adjacent to the trachea, while in the arytenoid cartilage it proceeds from the base to the apex.

Also, in 1930, Pancoast[19] stated that ossification of the laryngeal cartilages is easily shown at the earliest stages in roentgenograms of the larynx and suggested that the anatomic knowledge as presented in the textbooks of today be checked by extensive roentgen examina-

tion in a large number of living subjects. The information in our present-day textbooks of anatomy and histology, such as those by Cunningham,[20] Jordan,[21] Piersol,[22] Bremer,[23] and Maximow,[24] corresponds to that reported by Chievitz[3] half a century ago. The textbooks dealing with diseases of the larynx, however, give little if any space to abnormal aspects of the process or even to the possible relationship of the normal aspect to disease. For example, in the textbook by Thomson[25] and in the recent one edited by Turner,[26] there are no references to the process of ossification of the laryngeal cartilages as such, either physiologic or pathologic.

The findings of Baldenweck and Gauillard,[27] reported in 1933, correspond closely with those of the early anatomic writers. They stated that the roentgen shadow is denser at the centers of ossification as the process is more marked at these points, and that clear visualization of the laryngeal cartilages depends to a large extent upon the stage of pre-ossification and the "incrustation" of calcium. One year later, Terracol[6] reported a study in which he found no differences in the calcification of the cartilages in patients with dysfunction of the sex glands and in women whose ovaries had been removed as compared with others of the same ages.

Bergeat[12] found no evidence that chronic tuberculosis hastens the process of ossification. On the contrary, he found the ash content of the laryngeal cartilages less for the tuberculous persons than for the nontuberculous in the same age period, but in three cases of chronic gastric disease, two of carcinoma and one of ulcer, and in one case of Bright's disease in his series, the ash content of these cartilages was definitely increased. According to the observations of Fraenkel,[15] tuberculosis tends to delay ossification. Also disturbances of development in childhood may delay it, and chronic nasal infection, specific infection or constitutional disease, such as gout or diabetes, do not hasten the process, in his opinion.

In cases of tuberculosis of the larynx, Thost[5] found that true ossification of the cartilages does not progress normally; a more diffuse calcification is present and, as a result, the tuberculous larynx shows a fainter, less well defined roentgen picture. Weingärtner[16] reported that several cases of laryngeal tuberculosis in his series showed infiltration of calcium in the laryngeal cartilages, rather than actual ossification. Wulfson and Ginsburg[18] found a tendency to "demineralization" of these cartilages in such cases, which they regarded as related to general decalcification in this disease. They stated that scattered denser areas of ossification may be observed, especially in the lower part of the thyroid cartilage.

Thost[5] found that syphilis of the larynx tends to increase the intensity of ossification and to lead to the formation of hyperostoses and osteophytes. Wulfson and Ginsburg[18] stated that in this disease the roentgenogram shows an abnormal degree of ossification in the lower posterior border of the thyroid cartilage, occurring in irregular bands, and extending in all directions.

In carcinoma of the larynx, Thost[5] found that where the carcinoma is not of rapid growth causing early destruction of the cartilages, it appears to hasten the process of ossification. The thyroid cartilage showed complete ossification in two cases of laryngeal carcinoma in the series of Weingärtner.[16] Wulfson and Ginsburg[18] reported that the cartilages are often destroyed in this disease, but from the perichondrium new cartilage and bone tissue may be formed, which appear in the roentgenogram as scattered areas of calcified and ossified cartilage. In one case of cancer of the larynx presented by Baldenweck and Gauillard,[27] the roentgenogram showed the arytenoid cartilage calcified and clearly demonstrable and the thyroid cartilage largely destroyed.

More than half a century ago, Eppinger[28] stated that foreign bodies occurring in the larynx may have been formed there through some pathologic process. As early as 1901, Scheier[14] warned that in roentgenograms there is danger that a normal area of ossification may be mistaken for a foriegn body in the living subject. Ceresole[17] reported a case in which the patient was a man thirty-eight years of age, who, despite absence of symptoms, thought he had accidentally swallowed the metal key from a can of meat. A roentgenogram showed an opacity with the shape of a hook at the level of the median portion of the angulus of the thyroid cartilage. The shadow was found to represent ossification of the anterior portion of the thyroid cartilage at this point. In their recent article, Chamberlin and Young[9] stated: "Those cases in which isolated ossifications have occurred in parts of the cartilages which are superimposed upon the food passages, as seen in the lateral roentgenogram, are of particular interest on account of the possibility of confusion with foreign body. That these osseous shadows may be mistaken for foregin body has been proved by actual occurrence."

In a boy, twelve years of age, in whom a tracheotomy had been done, Weingartner[16] observed premature ossification of the cartilage in the region of the tube which had been inserted. Halsted,[29] in 1933, reported a case of a woman in which aphonia of about eight months' duration was the only symptom. Examination of the patient showed

the right vocal cord fixed and the trachea pushed to the left side. Roentgenograms showed a fusion of the third and fourth vertebræ and "what appeared to be a foreign body, a quarter of an inch long by one-sixteenth of an inch in width, lying horizontally at about the cricoid in the tracheo-esophageal wall." As there was a history of a minor injury in an automobile accident in which the patient was thrown forward and downward, Halsted[29] suggested that the foreign body might be a calcification of one of the laryngeal cartilages and that it was "thrown off" at the time of the accident and embedded in the larynx, interfering with the movement of the right cord. In 1867, Mackenzie[30] reported the case of a man, fifty-eight years of age, complaining of aphonia, who had fallen from "a great height" on his head and who, six months later, expelled the left arytenoid cartilage, completely ossified. In one of the three cases reported at different times by Gibb,[31] the patient had been thrown from a horse and had fallen on his head.

In the thirteen reports of cases of or associated with ossification of the laryngeal cartilages which occurred in the literature reviewed, six authors mentioned seven instances in which bone was expelled. Five of these, reporting six of the cases, were the earlier anatomists whose reports were published between 1867 and 1882. Mackenzie[30] and Gibb[31] reported trauma as a concomitant factor; Fyffe,[32] an abscess; Seiler,[33], cited by Wagner,[33] syphilitic laryngitis in two cases, and Wagner,[33] papilloma. In Fyffe's case "a piece of bone" was expelled; in the others the arytenoids, one or both. In the case reported by Weil,[34] in 1912, the patient expelled the ossified bodies of the arytenoids, extending as far forward as the processi vocali. A roentgenogram of the larynx showed "nothing striking"; although the laryngeal cartilages were "hazy" in appearance, there was no definite evidence of ossification of the remaining cartilages.

In a recent article Nelson and Hirsch[35] warned of the dangers of damage to the larynx from roentgen therapy. Hautant[36] and Jackson[37] called attention to the fact that the sensitiveness of the cartilages of the larynx to radiation is most marked at the site of greatest calcification. In all severe inflammatory reactions to endolaryngeal burns, whether they are due to the actual cautery, hot liquids, chemicals or radiation, the possibility of an ossified cartilage lying loose in the larynx should be considered, particularly when there is evidence of pus formation or a discharging fistula.

My interest in the rôle of ossification in some types of laryngeal disease was aroused by a case of carcinoma of the larynx in which the

patient expelled one of the superior cornua of the thyroid cartilage, completely ossified. Dr. Chevalier Jackson[38] confirmed my identification of this specimen. When the patient, a man forty-three years of age, first came under my observation on February 21, 1933, he was suffering from an extrinsic inoperable carcinoma of the larynx with an advanced metastasis into the neck. Indirect laryngoscopy showed an ulceration of the epiglottis, a marked involvement of the aryepiglottic folds, ulceration and complete fixation of both cords, and a subglottic tumor mass. Roentgen therapy was advised and was carried out by Dr. L. W. Cunningham[39] and Dr. W. McL. Shaw,[39] according to the method of Coutard, except that the dosage per day was slightly less than Coutard advocated, although the total dosage was the same. Treatment was begun on February 22nd and continued to March 24th. An improvement of the laryngeal picture was observed, and there was also improvement in phonation and deglutition. On June 5th, fourteen weeks after this therapy was started, the patient expelled an ossified superior cornu of the thyroid cartilage and at the same time expectorated a rather large amount of pus. Following this occurrence the patient showed a definite temporary improvement and was more comfortable for some time, but on the 11th of August a tracheotomy was required. Roentgen therapy was again instituted on September 21st and was given on alternate days until October 2nd. The patient died on March 26, 1934, as a result of a carcinomatosis, a laryngeal hemorrhage occurring three days before his death.

It is interesting to observe that in not one of the seven cases reported in the literature in which expulsion of ossified cartilage occurred was the presence of this foreign body diagnosed. Doubtless in all of these cases there was evidence of an inflammatory process, caused by the misplaced bone or sequestrum lying somewhere within the laryngeal tissues. In the case which came under my observation the condition was not diagnosed. Had a roentgen study been made, the foreign body might have been recognized. Occurrences such as featured these cases indicate the importance of more frequent roentgen studies of morbid conditions of the larynx, particularly where there is evidence of change caused by deep inflammatory processes. In these inflammatory processes in older persons in whom the laryngeal cartilages may have undergone a complete ossification, with the periosteum replacing the perichondrium, it would seem essential that a roentgen study be made. Thomson[25] mentioned perichondritis in the aged but made no reference to the fact that the cartilages may be transformed into bone. The possibility of inflammatory change,

such as an osteitis in the ossified cartilages, should always be considered and an effort made to differentiate this condition from a perichondritis. In some of the recent textbooks reference is made to perichondritis and chondral necrosis as etiologic factors of abscess of the larynx, but no mention is made of misplaced ossified cartilage, which also may be an etiologic factor of this condition. In a case reported by Fyffe,[32] in 1878, in which the patient expelled ossified cartilage, there was an abscess located between the middle of the thyroid cartilage and the lower jaw.

The subject of the ossification of the laryngeal cartilages is of more than classical interest, for its relation to some types of laryngeal pathology is worthy of careful consideration. While laryngoscopy, both direct and indirect, is indispensable, the laryngologist is in large measure dependent upon the roentgenologist for his study of this relationship, and with the improvement in recent years of roentgen equipment and technic the roentgenologist is now able to render invaluable aid in diagnosis, which could otherwise be gained only by autopsy.

Although it is generally conceded that age is the principal factor determining the advance of the process of ossification in the laryngeal cartilages, nevertheless the great variability of the age period at which it occurs points to the possibility of other etiologic factors, particularly in relation to its abnormal aspects. Since the literature reveals that the process has been found in a youth[16] twelve years of age and has not been found in a man[7] aged 103 years, the wide discrepancy in age suggests that modern research may find a causative agent such as endocrine disturbance, vitamin or mineral imbalance, improper metabolism or disturbed electrolyte balance which, when understood, will make possible the control of abnormal aspects of this phenomenon. Advances in the science of nutrition indicate, as Dr. R. A. Hetler[40] has said, that interrelationship in the concentration of minerals, vitamins and protein of the diet must have an influence on metabolic normality. Recent developments in research pertaining to the parathyroid suggest its importance in the production of bone.

CONCLUSIONS.

While age is the primary factor in ossification of the cartilages of the larynx, the wide variability of the age period suggests that there may be other etiologic factors which have not as yet been definitely determined.

In general, ossification of the laryngeal cartilages begins later and advances more slowly in women than in men.

Roentgen study shows that normally the process begins in the thyroid cartilage, occurs next in the cricoid cartilage, and last in the arytenoid cartilage.

Some diseases seem to retard ossification of the laryngeal cartilages while others seem to hasten it.

An ossified portion of laryngeal cartilage may as a sequestrum become an etiologic factor in abscess of the larynx.

The diagnosis of perichondritis is not infrequently made in the aged. A roentgen study might determine that the cartilages have been transformed into bone.

Roentgen studies of morbid conditions of the larynx, particularly where deep inflammatory processes are present, are invaluable aids to diagnosis and should be made with greater frequency.

111 West Adams Street.

REFERENCES.

1. Segond, L. A.: Mémoires sur l'ossification des cartilages du larynx. Arch. gén. de méd. Ser. 4, 15:364-378, 1847.

2. Schottelius, M.: Untersuchungen über physiologische und pathologische Texturveränderungen der Kehlkopf-Knorpel. Marburg University Thesis, 1879.

3. Chievitz, J. H.: Untersuchungen über die Verknöcherung der menschlichen Kehlknorpel. Arch. f. Anat. u. Physiol. Anat., Teil 1882:303.

4. Retterer, F.: Du mode d'ossification des cartilages du larynx. Compt. rend. Soc. de biol., 82:102-105, 1919.

5. Thost, A.: Der normale und kranke Kehlkopf des Lebenden im Röntgenbild. In: Fortschr. u. d. Geb. d. Röntgenstr. Erganzungs. bd., No. 31, 1931.

6. Terracol, J.: La calcification du larynx et la voix. Rev. franç. de phoniatrie, 2:20-24, Jan., 1934.

7. Hunt: Fractures of the Larynx. Am. J. M. Sc., 51:378, 1866.

8. Meunier, H.: Ossification de l'appareil hyoidien. Bull. Soc. anat. de Paris, 62:876-880, 1887; 63:382-386, 1888.

9. Chamberlin, W. E., and Young, B. R.: Ossification (so-called "Calcification") of Normal Laryngeal Cartilages Mistaken for Foreign Body. American Journal of Roentgenology and Radium Therapy, 33:441 (April), 1935.

10. Dreyfuss, R.: Normale und krankhafte Verknöcherungen im Kehlkopf und Luftröhre. Beitr. z. klin. Chir., 102:426-437, 1916.

11. Gardner, H. O.: Fractures of the Larynx. Arch. Otolaryngol., 18:449-457, 1933.

12. Bergeat, H.: Gewichtsbestimmungen an der Kehlkopfknörpeln. Arch. f. Laryngol. u. Rhinol., 6:198-212, 1897.

13. Kofler, K.: Histopathologische Veränderungen am Alterskehlkopf. Monatschr. f. Ohrenheilk., 66:1468-1472, 1932.

14. Scheier, M.: De l'ossification du larynx. Arch. internat. de laryngol., 11: 531-545, 1898; also in German (with additions) in Arch. f. mikr. Anat., 59:220-258, 1901.

Über die Architectur des ossificirten Kehlkopfs. Internat. Cong. Med. Trans., 1900, Sect. Laryngol., 325-327.

Zur Verknöcherung des menschlicken Kehlkopfes. Beitr. z. Anat., Physiol., Path. u. Therap. d. Ohres., 3:279-290, 1910.

15. Fraenkel E.: Über die Verknöcherung des menschlichen Kehlkopfs. Fortschr. a. d. Ged. d. Röntgenstrahl., 12:151-168, 1908.

16. Weingärtner, M.: Demonstration von Röntgenbildern aus dem Gebiete der Laryngologie. Berlin. klin. Wchnschr., 51:1477, 1914.

17. Ceresole, G.: Osservazioni radiologiche sull' ossificazione del margine anteriore della cartilagine tiroide e della porzione anteriore dell' anello cricoideo nei maschi. Arch. ital. di otol., 31:128-138, 1920.

18. Wulfson, S., and Ginsburg, W.: Die klinische Bedeutung der Röntgendiagnostik bei Kehlkopfkrankheiten. Röntgenpraxis, 2:158-170, 1930.

19. Pancoast, H. K.: Roentgenology of Upper Respiratory Tract, with Special Reference to the Larynx and Adjacent Structures. J. A. M. A., 95:1318-1321, 1930; also in Trans. Sect. Laryngol., Otol. & Rhinol., A. M. A., 1930:131-142.

20. Cunningham's Textbook of Anatomy. William Wood & Co., New York, 1931, p. 1069.

21. Jordan, H. E.: A Textbook of Histology. D. Appleton & Co., New York, 1927, p. 300.

22. Piersol's Normal Histology. J. B. Lippincott Co., Philadelphia, 1929, p. 234.

23. Bremer, J. L.: A Textbook of Histology. P. Blakiston's Son & Co., Philadelphia, 1930, p. 318.

24. Maximow, A. A.: A Textbook of Histology. W. B. Saunders Co., Philadelphia, 1930, p. 437.

25. Thomson, Sir St. Clair: Diseases of the Nose and Throat. D. Appleton & Co., New York, 1922.

26. Turner, A. L.: Diseases of the Nose, Throat and Ear. New York, Ed. 3, 1932.

27. Baldenweck, L., and Gauillard, R.: Recherches sur la radiographie normale et pathologique du larynx. J. de radiol. et d'electrol., 17:353-362, 1933.

28. Eppinger, H.: Pathologische Anatomie des Larynx und der Trachea. In E. Klebs' Handbuch der pathologische Anatomie, Berlin, 1880, Vol. 2, pt. 1.

29. Halsted, T. H.: Foreign Body Embedded in the Larynx. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 42:1229-1230, 1933.

30. Mackenzie, M.: Ossified (expectorated) Arytenoid Cartilage. Trans. Path. Soc., London, 18:31, 1866-67.

31. Gibb, G. D.: Complete Ossification of the Thyroid and Cricoid Cartilages. Trans. Path. Soc., London, 10:68, 1858-59; also in Lancet, 1:521, 1859.

Calcification of the Cartilages of the Larynx, Including the Arytenoid. Trans. Path. Soc., London, 12:51-52, 1860-61.

Exfoliations from the Thyroid Cartilage, Chiefly Composed of Phosphate of Lime. Trans. Path. Soc., London, 19:88-90, 1867-68.

32. Fyffe, W. J.: Observations on a Case of Ossification and Necrosis of the Laryngeal Cartilages. Trans. Bristol Med.-Chir. Soc., 1:4-9, 1878.

33. Wagner, C.: On Ossification of the Right Arytenoid Cartilage. Trans. Amer. Laryngol. Assoc., 4:114-117, 1882.

34. Weil, A. I.: Ossification and Subsequent Expulsion of Both Arytenoid Cartilages. Laryngoscope, 22:1124-1126, 1912.

35. Nelson, P. A., and Hirsch, E. F.: Roentgen Radiation Necrosis of Larynx and Other Structures of the Neck. J. A. M. A., Vol. 104, No. 18, May 4, 1935.

36. Hautant, A.: Radionécrose des Cartilages du Larynx. Ann. d. mal. de l'oreille, du larynx, du Nez et du Pharynx, 46, 1198, December 1.

37. Jackson, C., and Coates, G. M.: The Nose, Throat and Ear and Their Diseases. W. B. Saunders Co., Philadelphia, 1929, p. 845.

38. Personal communication to the writer.

39. Report supplied by Doctors Cunningham and Shaw from their records.

40. Personal communication to the writer.

ADDITIONAL REFERENCES.

Behn: Kehlkopfverknöcherung nachgewiesen am Lebenden. Fortschr. a. d. Geb. d. Röntgenstrahl., 4:43-44, 1900.

Bertoye, H.: Apercu sur les ecchondroses et exostoses du larynx. Ann. de mal. de l'oreille du larynx, 12:125-138, 1886.

Henckel, K. O.: Sur la structure fonctionelle des elements cartilagineux du larynx. Compt. rend. Soc. de biol., 108:648-649, 1931.

Sayama, M.: Über die Verknöcherung des Kehlkopfes bei Chinesen. J. Oriental Med., 14:53-54, 1931.

Seiferth, L. B.: Histologische Untersuchungen über Chondritis und Perichondritis des Kehlkopfs. Ztschr. f. Hals-, Nasen- u. Ohrenheilk., 24:555-565, 1929.

Travers, F.: Case of Ossification and Bony Growth of the Cartilages of the Larynx. Med.-Chir. Trans., 7:150-153, 1816.

LXII.

OSTEOMA OF THE NASAL ACCESSORY SINUSES.*

THOMAS EDWARD CARMODY, M. D.,

DENVER.

Osteomata of the nasal accessory sinuses are not common, but the older authors writing on the subject agree that the sinus most commonly affected is the maxillary. The later writers give the frontal as the most frequent. The reason is that the frontal was rarely opened. Bony tumors of the sphenoid sinuses are very rare.[1] Portmann and Retrouvey[2] are cited by Stout as finding only about thirty cases of frontal on record when they wrote their book on Cancer of the Nose in 1927. In 1928, Harris[3] reported 117 cases, and there have been reports of cases by several other authors since that time. Armitage[4] realized the discrepancy in the various estimates of the number of cases, and he merely cited the figures given by others, and concluded that the condition was a rare one. The great discrepancy between the figure of Portmann and Retrouvey and that of Harris, both of which were made within a year of each other, is probably due to wide divergence in the standard of diagnosis. Harris has accepted the figure of Gerber,[5] made in 1907, and added those cases he found after that date. Beck estimated 180 cases in 1930.[6] Any accurate estimate of the exact number of cases would require a careful check of the reports and tabulation of cases. Such a careful survey might be of real value.

Scudder[7] reports several osteomata of the jaws, both upper and lower, and skull, but only one apparently involves the sinuses and that the frontal. Skillern[8] does not mention osteoma by name but mentions stone in the sinuses, which from his description seems to be osteoma.

Most authors found evidence to support the statement that the condition is more common in males than in females, but in the six cases I report, three were in males and three in females. However, this group is too small in number to be of value in drawing deductions.

Osteomata of the sinuses have been reported in medical annals for years, although the exact date of the first such report is doubtful.

*Presented before the annual meeting of the American Laryngological, Rhinological and Otological Society, Toronto, Ontario, June 3, 1935.

They do not seem to be limited to the human being, as there are reports of their being found in animals by veterinarians.

The removal of such tumors was not very successful, and the mortality from attempted removal was very high until the advent of anesthesia, since which time it has been comparatively low. Diagnosis by the x-ray has increased the number of successful results markedly, as it is of value in determining the extent of involvement and the probable outcome.

Figures indicate that the condition is more common in young people—50 per cent of the cases occurring in adolescence and 80 per cent before the age of fifty—according to Armitage.[4] This is in a measure supported by the six cases I have to report, in which the ages were 11, 13, 23, 27, 35 and 42 years.

The rarity of the condition is best attested, probably, by the fact that no one author has a large number of cases to report. Knapp (cited by Armitage[4]) reported eight cases found in a review of 56,000 records, but these were not necessarily his own cases. A rapid review of the literature indicates that no single writer has reported more than two cases of osteoma of the frontal at one time. My report concerns four cases, and incidentally, although of what significance I cannot state, all have occurred within the past two and a half years.

The etiology of the condition is truly controversial. Harris has reviewed the various opinions on the subject well, and he found that the tumors have been thought to arise from embryonic cartilaginous cells at the junction of the ethmoidal and frontal (this agrees with Sutton and Scudder); from the periosteum of the sinus walls; from the diploe; from ossified polypi; syphilis (most of the older authors consider syphilis as the main etiologic factor but state that recurrence after removal is rare; in none of my cases was the Wassermann positive); trauma, sinus inflammation and tuberculosis. One of my cases gave definite history of trauma.

Harris[3] also found divergence as to the reports of the site of attachment. He quoted other reports of the site as being: the junction of the frontal sinus and ethmoid bones far forward, the under and inner wall of the frontal bone and the ethmoid, a pedicle inseparable from its frontal and ethmoid origins, continuous with the frontal bone at the inner wall of the sinus, the upper lateral wall in the frontal sinus, the infundibulum, the floor of the frontal sinus external to the duct, the anterior end of the junction of the ethmoid

with the frontal bone, the septum between the right and left frontal sinuses.

These tumors usually grow slowly, and there is a great divergence in size and involvement. The symptoms are as follows: (1) external deformity, (2) headache, (3) cerebral paralysis, (4) discharge, (5) vertigo. All symptoms are dependent upon the amount and type of involvement. There does not seem to be any definition of the direction of possible extension. In one of my cases the extension was posteriorly and into the orbit, and in another it was anteriorly and a slight dehiscence in posterior wall in same case. The external deformity may be in the form of a bulging process, and there may be proptosis of the eye.

The treatment, judging from the results obtained, is undoubtedly surgical. Since no one operator has had a sufficiently large number of cases to evaluate various methods of surgical procedure, the method must depend upon the particular case.

REPORT OF CASES.

CASE 1.—A. G., a white female, aged 23 years, was first seen on March 9, 1925, because two months previous she began to have headaches and pain over her left cheek, considerable nasal and postnasal secretion, and the left nostril felt obstructed. The family history was not pertinent.

The patient had had measles, mumps, whooping cough, chicken-pox and pneumonia. The tonsils and adenoids had been removed, and two months previous the left middle turbinate had been removed. Her appetite was good, but she slept poorly.

The roentgen examination showed slight increased density of right and left maxillary sinuses; right ethmoids were clear, but the left showed slight increased density; the right and left frontals and sphenoidals were clear. This indicated infection of right and left maxillary sinuses and left ethmoid. There was an area of increased density in the left upper third molar region with an impacted tooth above. This involved the posterior and inferior parts of the left maxillary sinus. The right and left third molar teeth were impacted.

On March 9, 1925, the left upper third molar tooth and a bony tumor were removed under ether anesthesia, operation was regular Caldwell-Luc technic; and two days later, again under ether anesthesia, a drainage tube was inserted in the left side of the neck under the angle of the jaw.

Eleven days later (March 21, 1925) the left maxillary sinus was irrigated and a quantity of broken down blood was obtained. Two months later (June 9, 1925) the discharge was clear, but three months later (September 7, 1925) irrigation fluid contained considerable pus. November 22, 1925, under ether anesthesia, maxillary sinus operation was performed and injection with alcohol of the left infra-orbital nerve, as I was not sure that sufficient pathology was present to account for pain.

One year after the first operation (March 3, 1926) irrigation of the affected maxillary sinus again returned cloudy fluid. Eight months later (November 13,

1926) the three impacted molar teeth were removed. For the next year and a half she was not troubled, but on March 5, 1928, and again on April 18, 1928, it was necessary to inject the left infraorbital nerve with 50 percent ethyl alcohol. After that she developed epileptiform convulsions and was unable to do her work, gradually getting weaker and was confined to hospital for several months before she died on May 10, 1930.

Autopsy failed to give a satisfactory anatomic or pathologic diagnosis.

CASE 2.—R. G., a white male, aged 11 years, was first seen on August 11, 1925. The father and brother were living and well, but the mother had pernicious anemia. The patient had had measles, mumps, pneumonia, "flu" and tonsillitis, and four and one half years previous a swelling of the left cheek had been noticed. At operation six months later, a mass of bone was removed from the region of the left maxilla. One year previous to the first consultation, deformity of the teeth was noticed and there was an increase in the size of the alveolar process.

On August 12, 1925, under ether anesthesia, the left maxilla was opened and the growth removed. No cavity that could be designated as a maxillary sinus was found. The pathologist's report was: Numerous small pieces of bone occupying the bulk of a hen's egg. Sections show that many of the pieces consist of normal bone with no canals, only a few clefts. No evidence of malignancy was found.

Diagnosis: Osteoma.

CASE 3.—P. G. P. When first seen on March 8, 1932, a white male, 27 years old (M. D. Interne), had suffered night and day for three weeks with continual headaches. The family history was negative. The patient had had a tonsillectomy in 1928; a tonsil tag removed in 1930. For three years he had been troubled with occasional frontal headaches which had recently become more frequent and more severe. They were accompanied by considerable postnasal discharge. Formerly the pain was more severe in the mornings, latterly the intensity did not vary. His general health and his appetite were good and he slept well.

Examination: Mouth.—The patient had had considereble dental work. There was a tonsil tag on the left, attached low on the posterior pillar. The posterior pharyngeal mucosa was inflamed, with granular hypertrophy. There was a large amount of thick yellow discharge in the nasopharynx and the mucosa of the palate was congested and swollen.

Nose.—The septum was straight. There was marked congestion of the right inferior and middle turbinates with thin mucopus and obstruction. On the left, the middle turbinate was inflamed, but there was no polypoid degeneration and no free pus.

Sinuses.—There was marked tenderness over the left frontal and supraorbital ridge. Transillumination on April 1, 1932, gave these results: maxillaries, left III, right II, frontals I.

Ears.—Excess of liquid cerumen, membrana tympana negative.

X-ray examination on March 24, 1932, showed the right frontal sinus to be normal, the left frontal was continuous with the left anterior ethmoid. There was a tumor mass occupying the space between the upper portion of the anterior ethmoid and the lower portion of the left frontal. There was no evidence of disease of the maxillaries or other sinuses. (Fig. 2.)

On April 2, 1932, under gas-ether anesthesia, the external plate over the lower part of the frontal was removed and a bony tumor about the size of a small olive

was revealed. There was considerable pus retained above the tumor with polypoid degeneration of the frontal mucosa. The tumor was apparently not attached and was easily removed. This revealed an intact inner plate. Much of the superior orbital wall was taken away, and the anterior part of the middle turbinate was removed and the nasofrontal duct was enlarged.

Eleven days after operation (April 13, 1932), the roentgen examination showed some cloudiness of the left frontal sinus, but no evidence of bony growth.

The diagnosis was osteoma of the left frontal sinus with retention.

Subsequent history as given in letter (May 6, 1935) from patient:

"After the operation you performed there was complete cessation of headaches until in the winter and spring of 1934 when I began to have dull headaches in the frontal region—mostly bilateral, but more severe on the left side. Accompanying this was rather severe nasal congestion. X-rays were taken at Passavant Memorial Hospital, but nothing definite was determined except sclerotic bone changes.

About the first of November, 1934, I had more severe headaches, throbbing pain around the left eye and considerable circumorbital edema, enough at least to make it look definitely puffy.

X-rays were again taken—this time at Washington Boulevard Hospital. From the finding of the lateral views especially, we all thought that there had been a recurrence of the tumor. So the latter part of November Dr. Lynn F. McBride again operated. To the surprise of everyone no tumor was found—the sinus wall smooth and well healed. He could not, however, find any sign of a nasofrontal duct or artificial opening, so apparently the sinus was completely closed.

Dr. McBride went in slightly above your incision. I was in the hospital for three or four days—recovered quite rapidly, the edema went down in about ten to fourteen days and today one has to look very closely to detect either scar. Dr. McBride made a rather large opening into the sinus, which has remained open very well.

I've only had one or two slight headaches since November and I need not tell you that it was a great relief to know that there was no recurrence and also to be relieved from those dull, constant, nagging headaches."

CASE 4.—R. B. K. On April 13, 1932, a white male, 35 years old, was referred to me by Dr. F. O. Kettelkamp of Colorado Springs. His chief complaints were a recently developed hesitancy in speech, partial paralysis of the right arm and leg, and upon leaning the head well forward and down and then rising to an erect position, a sensation as of fluid moving in his head. With the exception of one sister, who had an arrested case of pulmonary tuberculosis, the family history was unimportant. The patient had had diphtheria, and his tonsils had been removed eight years previous. About three years previous he blew his nose exceptionally hard, and a swelling of the left eye resulted immediately. He consulted a physician at once. The latter recommended wet witch hazel dressings, and in about three or four days the swelling had subsided. For two or three years he had suffered from headaches which were rather severe, but not frequent. These started in the frontal region and extended all over his head. When they were severe, things turned black before his eyes. He had had none since November, 1931 (five months previous). By occupation, the patient was a salesman, and on January 1, 1932, he noticed while with a customer that he was unable to talk. He went home at

once and soon recovered. The next day he noticed a slight lameness of the right arm which continued to grow worse. Ophthalmologic examination showed no visual disturbance whatsoever, although there was slight proptosis of the left eye downward and outward..

Examination: Throat.—There was an infected tonsil tag on the left, scar tissue contraction on both sides of the palate, the left side of the tongue showed slight apparent atrophy, the tip of the tongue seemed to deviate slightly to the right. There was no palsy of the soft palate.

The larynx, ears and nose were negative except for slight polypoid change of the tip of the left middle turbinate.

Palpation of the rim of the left orbit revealed on the upper rim a tip of bone about one half inch from the inner canthus. There was a question of actual dehiscence.

The neurologic examination revealed no cranial nerve paralysis. The reflexes were normal except that the right knee-jerk could not be elicited. There was paralysis of the right lower extremity and wasting of muscles of arm and leg; hesitation in speaking and sometimes motor aphasia.

The roentgen examination showed a large, irregular, bony tumor almost completely filling the left frontal sinus. This tumor had destroyed the roof of the orbit by pressure necrosis and pushing its way backward through the posterior wall of the left frontal sinus projected into the cranial cavity. There was a dumbbell shaped area of apparent rarification of the skull extending from the frontal sinus under the left parietal bone. This was thought to be air which was caught between the dura and the calvarium. (Fig. 1.)

On April 16, 1932, assisted by Dr. Kettelkamp, he was operated under ether anesthesia, incision was made below the left supraorbital ridge and an incision perpendicular to give more room. The plates of the frontal sinus were removed and the tumor was exposed. An irregular spine was found extending into the orbit, the roof of which was destroyed. Practically all the anterior portion of the interior wall of the frontal sinus was removed and the tumor pried loose. This was followed by a gush of blood and cerebrospinal fluid which escaped from an opening about the size of a dime in the dura and escape of air or gas. The edges of this opening appeared purulent and necrotic, and it apparently led into a smooth walled cavity which was either the remnant of a large empty brain abscess or the lateral ventricle. The cavity was packed with about twelve inches of one inch iodoform gauze. The vertical incision over the left frontal was closed with horse hair sutures. The outer angle of the incision below the brow was closed with skin clips.

The pathologist's report was: Section of pieces of bone the size of a pea showed osteoma. Later tissue and bone of about the size of a cherry was also sent to the laboratory. The sections showed dense, compact bone containing only a few small Haversian canals. There was no evidence of malignancy.

The diagnosis was osteoma.

The patient made an uneventful recovery except for a moderate seepage of cerebrospinal fiuid from the wound, and a diplopia resulting from removal of the tendon of the superior oblique muscle from its pulley. This disappeared.

On November 11, 1932 (seven months after operation), the patient had a convulsion which followed swimming and another attack six months later also after swimming. He was advised not to allow fluid in the nose. He was seen by Dr. Joseph C. Beck who concurred in advice.

Patient was seen in June, 1933, and had completely recovered even to the function of the muscles of the extremities and complete recovery of speech.

On January 20, 1935, he suffered another attack, which he describes as follows:

"It came on me very much the same as the others, that is, with no warning, and affected me very much the same. I was over visiting some friends one Sunday evening and right out of a clear sky it came on me. My right hand and arm started to shake and become stiff, my head commenced to jerk around to the right, my right leg started to straighten and jerk, I fell from the chair upon which I was sitting to the floor and that is the last I remember. When I came to, I was lying in bed and a doctor was standing along side of the bed. I was 'out' probably between thirty and forty-five minutes. Both immediately before and for some time after (an hour or so) I could not talk at all."

Perfectly normal since this time and continues with his work.

CASE 5.—S. M., a white girl, aged 13 years, noticed a lump on her forehead about one month previous to July 25, 1934. She had no pain. The family history was negative. The patient had had measles and chicken pox, and tonsillectomy had been performed five months previous. Her general health and her appetite were good and she slept well.

Roentgen examination of the sinuses on July 16, 1934, showed the frontals fairly large. There was a slight density of the left maxillary sinus and right and left ethmoids which indicated slight infection of those sinuses. There was a moderate sized opaque substance, probably osteoma, in the frontal sinuses slightly to the left of the midline, and it had apparently broken through the anterior frontal process.

On July 25, 1934, under ether anesthesia, the tumor was removed from the left frontal sinus, both frontals were opened and as the septum was involved and part of the growth found in right sinus, the membrane was removed in its entirety.

Recovery was uneventful and complete. (Fig. 5.)

CASE 6.—B. H., a white woman, aged 42 years, was referred to me by Dr. Robert Packard on June 23, 1934. Except for an aunt who died of carcinoma of the breast, the family history was negligible. The patient had had measles, mumps, and chicken pox in childhood, and an appendectomy and complete hysterectomy ten years previous. She had had sinus trouble ever since five years of age; at eleven years she remembered having a very bad cold and a broken septum, but her memory was not good. Her general health and appetite was good, but she was nervous.

Roentgen examination was made of the sinuses. The frontals were of average size. There was an area of increased density practically filling the left frontal sinus which had the appearance of an osteoma. It was apparently attached to the posterior wall. There was slight increased density of the right and left ethmoids and the right and left maxillary sinuses suggesting a moderate infection of those sinuses. There was no evidence of retention. (Fig. 4.)

On September 1, 1934, under avertin anesthesia the tumor was removed from the left frontal sinus.

Three months later the patient reported her memory was much improved and there was a lessening of the nervousness.

TABULATION.

There is considerable divergence as to the number of osteomata of the nasal accessory sinuses reported in the literature. This may

be due to incompleteness of early reports coupled with difficulty in obtaining the originals for perusal. No recent author has tabulated the recorded cases. The table which follows (Table I) is a compilation made by examination of reports obtainable locally or abstracted and noted by other authors. Wherever the original was not examined the author whose authority is relied upon is stated.

CASE NO.	AUTHOR	SEX	AGE	LOCATION	REFERENCE
1.	Andrews, J. A.	M.	48	Right ethmoid and orbit	Medical Record, 32:261, September 3, 1887.
2.	Andrews, J. A.	F.	19	Left frontal and orbit	Ibid
3.	Ardenne			Frontal	Rev. Hebd. de Laryng., 1:641, 1909 (Harris).
4.	Armitage, G.	M.	36	Both frontals	British Journal of Surgery, 18: 565, 1930-31.
5.	Arnold	M.	24	Left frontal and orbit	Arch. f. Path. Anat., 57:148, 1873 (Andrews).
6.	Arnold			Left frontal and roof of orbit	Arch. f. Path. Anat., 57:148, 1873 (Andrews).
7.	Axenfeld			Frontal	Klin. Monatschr. f. Augenhk., 42:229, 1904 (Harris).
8.	Banga	M.	18	Right frontal and orbit	Deutsche Ztschr. f. Chir., 4: 486, 1874 (Andrews).
9.	Barnhill, J. F.	F.	16	Frontal	Annals of Otology, Rhinology and Laryngology, 27:1239, 1918; also 27: 1115, 1918.
10.	Beck, J. C.	M.	49	Both frontals	Laryngoscope, 40:512, July, 1930.
11.	Berge			Frontal	Lyon, L'oeil et les Tumeures solides du Sinus Frontal, 1903 (Harris).
12.	Berger, M.	F.	19	Inferior maxillary	La Semaine Medicale, p. 69, February 12, 1896.
13.	Birkett	F.	15	Left frontal and orbit	Guy's Hospital Reports, p. 505, 1871 (Andrews).
14.	Boardman and Donovan			Frontal	Journal of the American Medical Association, 1918 (Harris).
15.	Bouyer			Frontal	Ann. de la Chir. et étrangere, 3:242, 1841 (Armitage).
16.	Bessel-Hagen	F.	26	Left frontal and orbit	Zentralbl. f. Chir., 16:900, 1889.
17.	Birsch-Hirschfield			Frontal	Munch. med. Wchnschr., 51: 234, 1904 (Harris).

CASE NO.	AUTHOR	SEX	AGE	LOCATION	REFERENCE
18.	Bornhaupt, T.	F.	18	Left frontal and orbit	Arch. f. klin. Chir., 26:595, 1881.
19.	Boyd, S.	M.	20	Left frontal	Lancet, 2:607, September 20, 1890.
20.	Browder, J.	M.	16	Left frontal and orbit	Archives of Otolaryngology, 9:297, 1929.
21.	Bryant	M.	24.	Right frontal and orbit	British Medical Journal, 2:631, 1872 (Andrews).
22.	Buys			Frontal	Arch. Ital. di Otol., 36:298, 1925 (Harris).
23.	Cargill			Frontal	Transactions Ophth. Soc. of the United Kingdom, 32: 195, 1911-12 (Harris).
24.	Chapman, V. A.	F.	52	Both frontals and ethmoids	Journal of the Michigan State Medical Society, 15:18, January, 1916.
25.	Citelli			Frontal	Ann. d. Malad. d'ore Illi du Larynx, etc., p. 483, 1913 (Harris).
26.	Coffin			Frontal	Laryngoscope, 17:525, 1917 (Harris).
27.	Colson, Z. W.	M.	38	Right frontal	Laryngoscope, 43:677, August, 1933.
28.	Coppez			Frontal	Clinique Brux, 9:81, 1895 (Harris).
29. thru 34.	Coppez			Frontal	Presse Med. Belge, 51:293, 1899 (Harris).
35.	Culbert, W. L.	M.	43	Frontals, ethmoidals and sphenoidals	ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 27:1203, December, 1918.
36.	Cushing, H.	M.	23	Orbito-ethmoidal	Surgery, Gynecology and Obstetrics, 44:721, June, 1927.
37.	Cushing, H.	M.	22	Orbito-ethmoidal	Surgery, Gynecology and Obstetrics, 44:721, June, 1927.
38.	Cushing, H.	M.	41	Orbito-ethmoidal	Surgery, Gynecology and Obstetrics, 44:721, June, 1927.
39.	Cushing, H.	M.	35	Orbito-ethmoidal	Surgery, Gynecology and Obstetrics, 44:721, June, 1927.
40.	Dahman				Ztschr. f. Hals, Nasen u. Ohrenh., 1:261, 1922 (Fetissof).
41.	Davies			Frontal	Transvaal Medical Journal, 2: 119, May, 1907 (Harris, Portmann and Retrouvey[2]).
42.	Demarquay, M.			Right frontal	Gaz. Med. de Paris, April 20, 1867 (Heath[9]).

CASE NO.	AUTHOR	SEX	AGE	LOCATION	REFERENCE
43.	Dolbeau	M.	21	Right frontal and orbit	Mem. de l'Acad. Roy. de Med., p. 12, 1871 (Andrews).
44.	Dubar and Potel			Frontal	Echo med. du Nord., No. 6, February 5, 1911 (Portmann and Retrouvey[2]).
45.	Dudon			Frontal	Mem. et Bull. Soc. de Med. Chir. de Bordeaux (Harris).
46.	Duka			Right maxillary	Transaction of Path. Soc. of London, 17:256, 1866 (Andrews).
47.	Falgar			Maxillary antrum	esp. Rev. Laryngol., July-August, 1912 (Portmann and Retrouvey[2]).
48.	Fallas				Bull. d'Oto., Rhinol., Laryngol., 20-49 (Jackson et al[10]).
49.	Fergusson, Wm.	M.	21	Left orbit and sphenoid	Lancet, p. 310, 1868 (Andrews, Heath[9]).
50.	Fetissof, A. G.	M.	24	Left frontal	ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 38:404, 1929.
51.	Fetissof, A. G.	M.	20	Right frontal	ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 38:404, 1929.
52.	Fetissof, A. G.	F.	19	Right frontal	ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 38:404, 1929.
53.	Fetissof, A. G.	M.	20	Left frontal	ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 38:404, 1929.
54.	Fridenberg, P.	M.	21	Right orbit and ethmoid	Transactions American Ophthalmological Society, 10: 83, 1903.
55.	Friedenberg			Frontal	Med. Monatsschr., 10:502, 1898 (Harris).
56.	Garrettson, W.	M.	19	Frontal, ethmoid and orbit	Archives of Otolaryngology, 5:135, 1927.
57.	Garrettson, W.	F.	61	All sinuses	Archives of Otolaryngology, 5:135, 1927.
58.	Garrettson, W.	M.	46	Right maxillary	Archives of Otolaryngology, 5:135, 1927.
59.	Gault				Bull. d'Oto., Rhinol., Laryngol., 19-194, 1921 (Jackson et al[10]).
60.	Gerber			Frontal	Arch. Internat. de Laryngol., 23:1, 1907 (Harris).

CASE NO.	AUTHOR	SEX	AGE	LOCATION	REFERENCE
61.	Goodyear, H. M.	M.	32	Right frontal and orbit	Laryngoscope, 35:751, 1925.
62.	Goris			Frontal	Arch. Franco-Belges de Chir., 25:411, 1922 (Harris).
63.	Goyanes			Frontal	Rev. de Med. y Chirurg., 42: 201, 1904 (Harris).
64.	Grossman, K. M.	M.	24	Right orbit involved frontal	Ophthalmic Review, 6:341, 1887.
65.	Güntzer, J. H.	F.	37	Right maxillary	Medical Record, 78:12, July 2, 1910.
66.	Haas			Frontal	Beitr. z. klin. Chir., 31:139, 1901 (Culbert).
67.	Hajek			Frontal	Wien. klin. Wchnschr., 33: 325, 1920 (Harris).
68.	Handley, W. S.	M.	35	Right frontal	Proc. Royal Soc. Med. Clinical Section, 5:52, 1911-12.
69.	Harris, R.	M.	30	Frontal	Laryngoscope, 38:331, 1928.
70.	Harris, R.	M.		Frontal	Laryngoscope, 38:331, 1928.
71.	Hasslauer				Arch. f. Laryngol. u. Rhin., 10:60, 1900 (Wright[11]).
72.	Hastings, H.			Specimen left frontal	Annals of Surgery, 41:624, 1905.
73.	Henrici			Maxillary	Med. Klinik No. 11, p. 432, 1911 (Portmann and Retrouvey[2]).
74.	Hewitt			Frontal and orbit	St. George's Hospital Reports, 2:14, 1867 (Andrews).
75.	Hewitt	F.	24	Frontal	St. George's Hospital Reports, 2:14, 1867 (Andrews).
76.	Hilton	F.	30	Left frontal and orbit	Guy's Hospital Reports, 1:493, 1836 (Andrews).
77.	Hilton	M.	13	Maxillary and ethmoids	Guy's Hospital Reports, 1:493, 1836 (Andrews).
78.	Hoppe, C.	F.	22	Frontals and ethmoids	In Bornhaupt.
79.	Hutchinson	F.	50	Right orbit involved frontal	Illustrations of Clinical Surgery, 1875, p. 9 (Andrews).
80.	Hutchinson	M.		Frontal and orbit	Illustrations of Clinical Surgery, 1875, p. 9 (Andrews).
81.	Ingersoll, J. M.	M.	14	Frontal	Annals of Otology, Rhinology and Laryngology, 27:1116, 1918.
82.	Ischunin			Right frontal	Khir. Vestnik., 61:1, 1890 (Harris).

CASE NO.	AUTHOR	SEX	AGE	LOCATION	REFERENCE
83.	Jaboulay				Gaz. des Hopit., No. 135, 1906 (Portmann and Retrouvey[2]).
84.	Jackson			Frontal	Transaction of the Amer. Med. Assoc., 19:299, 1892 (Culbert).
85.	Jacques			Frontal	Rev. Med. De l'st, 47:471, 1918 (Harris).
86.	Jobert			Frontal	Mem. de l'Acad. Roy. de Med., p. 18, 1871.
87.	Johnston, W.	F.	19	Left ethmoid	Transaction of Pacific Coast Oto-Ophthalmologic Society, 20:56, 1932.
88.	Jones and Holland	F.	35	Frontal	British Medical Journal, 2: 1367, Nov. 17, 1906.
89.	Kikuxi			Frontal	Beitr. z. klin. Chir., 3:489, 1888 (Harris).
90.	Kikuxi			Frontal	Beitr. z. klin. Chir., 3:489, 1888 (Harris).
91.	Knapp	M.	14	Left frontal and orbit	Graefe's Arch. f. Ophth., 8: 230, 1861. Archives of Ophthalmology, 9 : 464. 1880.
92.	Knapp		48		Graefe's Arch. f. Ophth., 8: 230, 1861. Archives of Ophthalmology, 9 : 464, 1880.
93.	Lang			Frontal	Deutsche med. Wchnschr., 14: 254, 1919 (Harris).
94.	Lang, W. and Armour, D.	M.	19	Left frontal and orbit	Proc. Royal Soc. Med. Section of Ophthalmology, 47:68, 1918.
95.	Leavenworth, R. O.	M.	23	Left frontal	Laryngoscope, 43:677, August, 1933.
96.	Lee, F. H.	M.	17	Right frontal and orbit (colored)	Laryngoscope, 35:291, 1925.
97.	Lewis, A. C.			Frontal	Amer. Jour. Ophthalmology, May, 1926 (Harris).
98.	Liras			Frontal	J. de Med. de Bordeaux, 25: 409, 1895 (Harris).
99.	Lucas-Champonnierre			Frontal	Bull. et Mem. Soc. Chir. de Paris, 12:807, 1886 (Harris).
100.	MacKenty, J. E.	M.		Frontal	ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 27:1116, 1918.

CASE NO.	AUTHOR	SEX	AGE	LOCATION	REFERENCE
101.	Malan, A.	F.	26	Frontal, ethmoids and orbit	Rev. oto-neuro-oftal., 11:47, Jan.-Feb., 1934. Abs. in Yearbook, 1934, p. 177.
102.	Manasse	M.	16	Right frontal	Journal of Laryngology, 25: 424, 1910.
103.	Manninger			Frontal	Orvosti Betil-Budapest, 47: 163, 1903 (Harris).
104.	Martel and Behague				Arch.-med. belges, June, 1921 (Portmann and Retrouvey[2]).
105.	Michon, M.	M.	20	Right maxillary	Mem. de la Soc. de Chir. de Paris, 2:615, 1851 (Andrews).
106.	Mott				Amer. Jour. Med. Science, 33: 35, 1887 (Culbert).
107.	Mouret et Dejean				Rev. d'oto-neuro-ocullistique, 4:585, 1926 (Fetissof).
108.	Neilson				Centralbl. f. Hals, Nasen u. Ohrenh., 11:108, 1927 (Fetissof).
109.	Norris			Frontal	Transaction of American Ophthalmologic Society, 8:67, 1897 (Culbert).
110.	Paget, J.	F.	20	Left orbit, sinuses probably involved	Lectures on Surgical Pathology, Phila., Lindsay & Blakiston, 1860, p. 459.
111.	Panas	F.	18	Right orbit and ethmoids	Arch. d'Ophth., 4:289 (Andrews).
112.	Parsell, L. A.	M.	32	Right frontal	Archives of Otolaryngology, 16:863, 1932.
113.	Patel et Pellanda				Lyon Med., Sept. 17, 1905 (Jackson et al[10]).
114.	Pfeiffer, W.	M.	24	All sinuses, especially frontals	Berl. klin. Wchnschr., 29:375, Feb. 19, 1912.
115.	Phillip				Rev. Hebd. de Laryng., 2-194, 1911 (Jackson et al[10]).
116.	Piazza			Frontal	Arch. Internat. de Laryng., 4: 619, 1924 (Harris).
117.	Probert, C. C.	M.	15	Right frontal	Jour. Michigan Med. Soc., 5: 304, June, 1916.
118.	Reh			Frontal	Deutsche Med. Wchnschr., 49: 215, Feb. 16, 1923 (Harris).
119.	Righetti			Frontal	Boll. d'Acad. Med. di Perugia No. 51, 1925 (Harris).
120.	Roux	M.		Right frontal	Mem. de l'Acad. Royale de Med., p. 4, 1871 (Andrews).

CASE NO.	AUTHOR	SEX	AGE	LOCATION	REFERENCE
121.	Sackin, D.	M.		Both frontals	Jour. of Ophth., Otol. and Laryngol., 33:47, February, 1929.
122.	Sackin, D.			Sinuses	Jour. of Ophth., Otol. and Laryngol., 33:47, February, 1929.
123.	Sackin, D.	M.	35	Both frontals	Jour. of Ophth., Otol. and Laryngol., 33:47, February, 1929.
124.	Sattler, R.	M.	25	Right orbit, involved frontal and ethmoids	Transactions Amer. Ophthal. Soc., 7:553, 1896.
125.	Sattler, R.				Cincinnati Clinic-Lancet, 38: 137, 1897 (Harris).
126.	Serra				Centralbl. f. Hals, Nasen u. Ohrenh., 1927 (Fetissof).
127.	Sewall, E. C.	M.	25	Left frontal	ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 27:275, 1918.
128.	Sipocz			Frontal	Post. med. Chir. Prest (Budapest), 39:1135, 1903 (Harris).
129.	Stolpe			Frontal	Arch. Ohren, Nasen u. Kehlh., 105:75 (Harris).
130.	Taranto			Frontal	Paris Thesis, 1901 (Culbert).
131.	Tauber, A. S.			Frontal	Khirurgia (Moscow), 3:41, 1898 (Harris).
132.	Thomas, G. F.			Frontals, ethmoids, orbit	Amer. Jour. Roent., 5:341, 1918.
133.	Tillman			Frontal	Arch. f. klin. Chir., 32:677, 1885 (Culbert).
134.	Turner			Specimen orbit from frontal	Anat. Museum of Univ. of Edinburgh Preparation No. 456 (Andrews).
135.	Tweedy	M.	25	Left frontal and orbit	Royal London Ophthalmic Hospital Reports, 10:303, 1882 (Andrews).
136.	Veasey, C. A.	F.	30	Sinuses and orbit	Annals of Ophthalmology, 25: 699, 1916.
137.	Weingartner	M.	42	All sinuses	Berl. klin. Wchnschr., 2:1710, Oct. 12, 1914.
138.	Weiss			Frontals	Bull. de la Soc. Anat., 26:220, 1852 (Bornhaupt).
139.	Zimmerman			Frontal	Deutsche Ztschr. f. Chir., 57: 354, 1900 (Harris).

METROPOLITAN BUILDING.

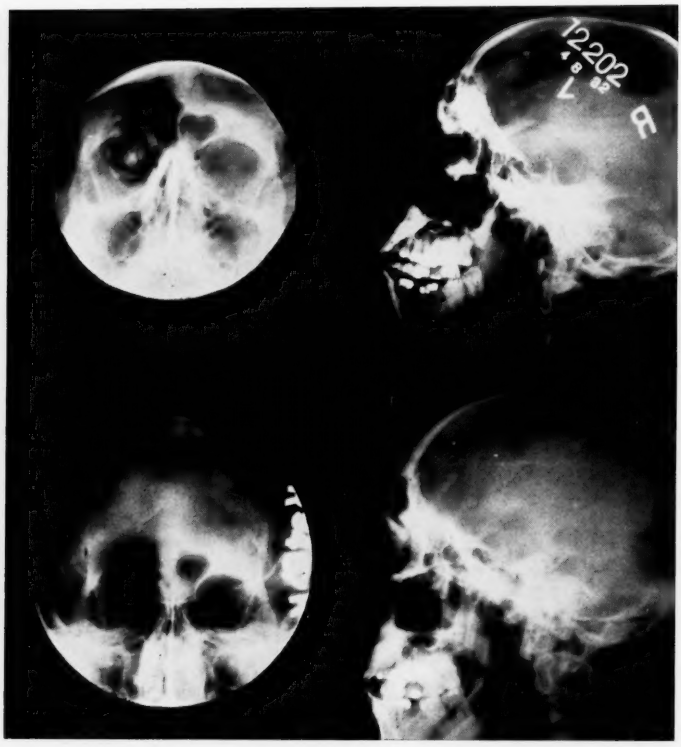

Fig. 1. Case IV.

A. Postero-anterior roentgenogram showing large osteoma in the left frontal sinus.

B. Lateral roentgenogram showing osteoma and large area of rarefaction in cranium.

C.-D. Postero-anterior and lateral roentgenograms showing result in same patient after operation.

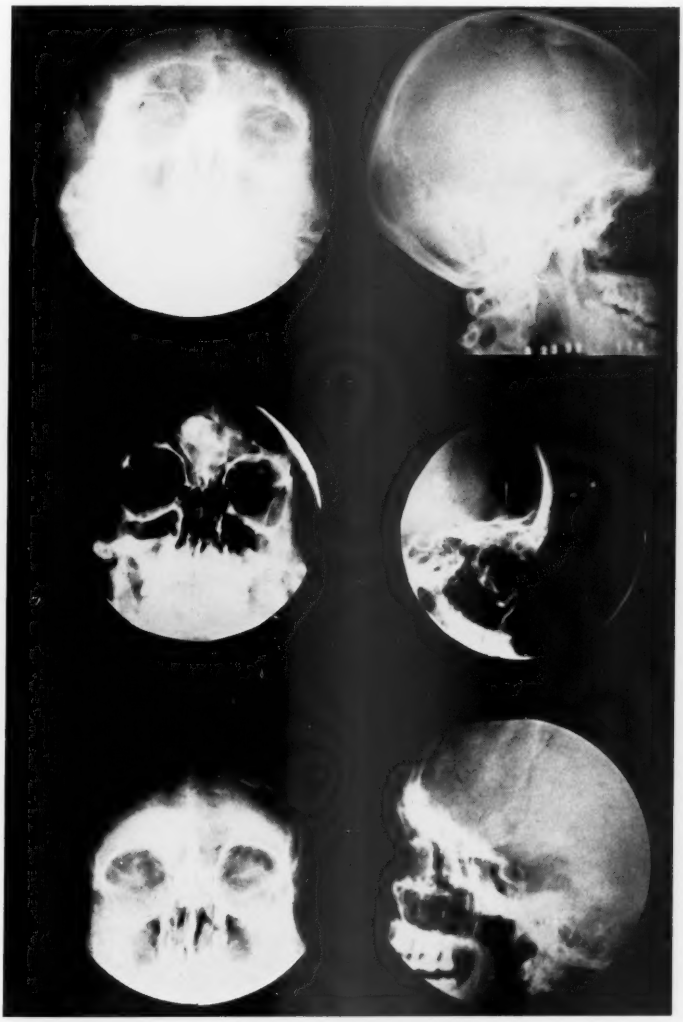

Fig. 2. Case III.—Postero-anterior and lateral roentgenograms showing osteoma in the left frontal sinus.

Fig. 3. Case V.—Postero-anterior and lateral roentgenograms showing osteoma in frontal sinuses. On lateral roentgenogram, note anterior displacement of soft tissue.

Fig. 4. Case VI.—Postero-anterior and lateral roentgenograms showing osteoma in left frontal sinus.

Fig. 5. Case V, left.—Photograph of patient before operation. Note bulging of forehead.
Right.—Same patient after operation showing excellent cosmetic result.

BIBLIOGRAPHY.

1. Stout, Arthur Purdy: Human Cancer; Etiological Factors; Precancerous Lesions; Growth; Spread; Symptoms; Diagnosis; Prognosis; Principles of Treatment. Lea and Febiger, Philadelphia, 1932.

2. Portmann, Georges, and Retrouvey, Henri: Le Cancer du Nez, Des Fosses Nasales, Des Cavites Accessoires et du Naso-pharynx. Gaston Doin et Cie, Paris, 1927.

3. Harris, Robin: Osteoma of the Frontal Sinus: Report of Two Cases. Laryngoscope, 38:331, 1928.

4. Armitage, George: Osteoma of the Frontal Sinus: with Particular Reference to Its Intracranial Complications and with the Report of a Case. British Journal of Surgery, 18:565, 1930-31.

5. Gerber: Archives Internationale de Laryngologie, 23:1, 1907.

6. Beck, Joseph C.: Some Uncommon Types of Neoplasms About the Head. Laryngoscope, 40:512, July, 1930.

7. Scudder, Charles L.: Tumors of the Jaws. W. B. Saunders Co., Philadelphia and London, 1912.

8. Skillern, Ross Hall: Catarrhal and Suppurative Diseases of the Accessory Sinuses of the Nose, 3rd Edition. Philadelphia, Lippincott and Co., 1920.

9. Heath, Christopher: Injuries and Diseases of the Jaws. J. and A. Churchill, London, 1884.

10. Jackson, Chevalier; Coates, George M., and Jackson, Chevalier L.: The Nose, Throat and Ear and Their Diseases. W. B. Saunders Co., Philadelphia and London, 1930.

11. Wright, Jonathan: A History of Laryngology and Rhinology. Lea and Febiger, Philadelphia and New York, 1914.

LXIII.

BRANCHIAL AND THYROGLOSSAL DUCT CYSTS AND FISTULAS.*

JOHN MACKENZIE BROWN, M. D.,

LOS ANGELES.

The presentation of this subject is prompted by the fact that although laryngologists are consulted as frequently as anyone in our profession for the treatment of these conditions, there is very little to be found on the subject in laryngologic literature.

DEVELOPMENT.

A knowledge of the transformation of the embryonic to the adult pharynx is of practical importance. As expressed by Sir Arthur Keith,[1] it aids us in understanding the origin of these cysts and fistulas in the neck and throws more light on the nature and anomalies of the thymus, thyroid and tonsil.

During the first two weeks of embryonic life five branchial arches are formed in the neck of the embryo. These produce ridges, separated by grooves, which are found on the external lateral surfaces of the embryonic neck. They correspond to the gill-arches of fishes, but in these lower animals the arches are separated by actual clefts, through which respiratory water flows. In man they never develop such a respiratory function but are modified and take part in the formation of various structures in the mouth, pharynx and larynx. There are, then, definitley developed during the sixth and seventh week, four external grooves, with four internal pouches lying opposite on the inside of the pharynx, and an arch or supporting skeletal element on either side of each pouch. The first two arches are much larger than the other three, so overlap and obscure them, and the second arch becomes attached to the thoracic wall of the embryo. Thus is produced beneath, a sinus which becomes closed off, and under normal conditions the epithelial lining of the sinus is absorbed. Sometimes, however, the epithelial lining persists and the embryonic cervical sinus or a part of it (particularly that related to the second cleft), forms the cervical cyst of the adult. Likewise, a pinching off and nonabsorption of the entodermal lining of the pharyngeal

*Presented before the annual meeting of the American Laryngological Association, Toronto, Ontario, May 29, 1935.

pouches on the inside of the embryonic neck may produce internal cysts. Further, if the thin wall intervening between the embryonic pouch internally and the groove externally breaks through, another interesting pathologic condition results in the adult, a cervical fistula, opening directly from the pharynx to the outside.

While the tonsils, the thymus and parathyroid glands develop from the lining membrane of the side-walls of the embryonic pharynx, the thyroid gland is formed from tissue found originally in the floor of this cavity. During the third week a dimple appears in the floor of the pharynx at the level of the first pouch. This dimple enlarges until a sac is formed attached to the point of origin by an elongated neck. Around this point of origin there develops in the floor of the pharynx, the tongue, and the original point of origin of the thyroid gland remains marked in this organ as the foramen caecum. The thyroid grows downward in front of the anterior wall of the pharynx, and its elongated neck becomes the thyroglossal duct. During the sixth week of embryonic life this duct usually loses its lumen and atrophies, the only portion of the duct persisting in the adult being its lower portion, which forms the pyramidal lobe of the thyroid gland. Failure in atrophy of portions of the thyroglossal duct results in accessory thyroids, cysts or even fistulas occurring in the adult, usually in the midline of the neck, and anywhere from the foramen caecum of the tongue down to the pyramidal lobe of the thyroid gland at the level of the thyroid cartilage.

PATHOLOGY.

Theories concerning the origin of cysts and fistulas may be outlined as ascribed to the following:

1. Rupture of the embryonic membrane separating the branchial clefts.

2. Failure of malformed clefts to unite or fuse properly.

3. Incomplete retrogression of the branchial apparatus.

4. Anomalous development of the vestigeal remnants of a branchial cleft.

5. The persistence of a cervical sinus.

6. Remnants of the thymic duct.

7. And, in the case of a true thyroglossal duct cyst, its lumen may not become obliterated and it becomes either an enclosed cyst or an open secreting sinus.

The cysts derived from the ectoderm contain squamous epithelium and a grumous putty-like substance. Those from the entoderm contain columnar epithelium and a mucoid substance containing cholesterin. However, some cysts contain both types of epithelium. When the cyst becomes degenerated from irritation or infection, the walls become infiltrated with the elements of chronic inflammation and firmly adherent to the surrounding structures making dissection very difficult. Thyroglossal duct cysts and fistulas are usually lined with squamous epithelium and the content is grumous and, when infected, purulent.

CLASSIFICATION.

The classification of these cysts and fistulas has been given by Andrews[2] as follows:

1. Cysts with no internal or external openings.
2. Cysts and fistulas opening internally.
3. Cysts and fistulas opening externally.
4. Fistulas with internal and external openings.

They are classified by Bailey,[3] according to position, as superficial or deep; auricular, parotid, sublingual, submaxillary, pharyngeal, or tracheal; and by others as to the cleft giving origin, as to the contents, and the type of lining epithelium. (Hyndman and Light[4]).

CLINICAL ASPECTS.

Cysts without a fistulous tract. The first complaint of the patient is usually of a soft swelling in the neck with practically no other symptoms. As the cyst increases in size, however, it may press upon various structures, causing hoarseness, coughing or difficulty in breathing and swallowing, depending upon the direction of growth. Carp[5] reports a case with persistent hacking cough due to pressure on the vagus, the symptoms subsiding after excision of the fistula. Thomson[6] reports a case of fixation of the left vocal cord in which at opration the cyst was found attached to the left side of the larynx. Pain and tenderness are infrequent symptoms and usually due to infection.

Cysts other than those preauricular are all anterior to or under the sternomastoid muscle. They have never been reported as bilateral.

Cysts with a fistulous tract draining internally may present any of the foregoing symptoms, but with this type there is always a

history of intermittent variations in the size of the tumor. This is due to the emptying of the cyst through its fistulous tract. In one of my cases, following tonsillectomy, the tumor decreased in size, probably the result of opening the fistulous tract. A common history in this type is that the patient had a discharge in the throat, and, on careful inspection, a secretion may be found coming from the mouth of the tract, usually in the supra- or infra-tonsillar fossa. They are seldom noticed unless they are of sufficient size to drain habitually. This condition is frequently precipitated by tonsillectomy. (Hyndman and Light).[4]

Cysts with fistulous tracts draining externally likewise have fluctuations in the size of the tumor. The outstanding complaint of those with external openings is periodic drainage which may be clear tenacious mucus, or purulent. Coplin[7] stated that stimulation of the salivary secretion by mastication sometimes excites secretion from the sinus, even when it does not communicate with the alimentary canal. The external orifice is frequently pigmented and may present a dimpling or a tab of skin containing cartilage. Virchow,[8] in 1861, reported one case of multiple openings at the junction of the sternomastoid muscle with the clavicle. Nearly all cysts with fistulas, whether internal or external, are infected to a varying degree.

Complete branchial fistulas with internal and external openings are uncommon. Six cases are reported by Kleinert[9] from the Massachusetts General Hospital. They may be unilateral or bilateral. In Hyndman and Light's[4] series, 16.8 per cent were bilateral.

A thyroglossal duct cyst without a fistulous tract may be located at any position along the former course of the embryonic thyroglossal duct. Its symptoms are those of swelling or pressure, or both, as evinced by difficulty in swallowing, coughing, hoarseness, breathing, and in fact all of the symptoms seen in a branchial cleft cyst. These cysts are practically always in the midline, and seldom above the hyoid. However, Klingenstein and Colp[10] reported a case in which the cyst was so far lateral to the median line that a thyroglossal duct cyst was not entertained.

A thyroglossal duct cyst with a fistulous tract either opens internally at the foramen caecum or externally in the midline of the neck, between the hyoid bone and the suprasternal notch, though the opening may be lateral. The symptoms are also similar to those of branchial cleft cysts with fistulas draining internally or externally. Infection is the rule in this type.

DIAGNOSIS.

Differential diagnosis involves the following:

1. *Adenitis*, which is usually bilateral and associated with some focus of infection. Tuberculous adenitis in children must be determined by the history, the tuberculin test, and bacteriologic examination of the contents. Injection of lipiodol and subsequent x-ray examination is of considerable value in differentiation, as tuberculous glands of the neck present an irregular outline after injection, as stated by Wagensteen.[11]

2. *Cystic hygromata*, which are allied with lymph cysts, are translucent and usually situated in the lower half of the neck.

3. *Venous hemangiomata* decrease in size on pressure.

4. *Lipomata*. The contents cannot be aspirated but may strongly simulate the cyst otherwise.

5. *Sublingual epithelial cysts* are usually congenital. The symptoms are the same as branchial cysts and can only be differentiated by the pathologist. Dr. John B. Hitz[12] reports an interesting case of this type.

6. *Dermoid cysts*, granulas and tumors of the thyroid must be differentiated from thyroglossal duct cysts. This can be done by lipiodol injection and x-ray examination, together with microscopic examination of the contents of the cyst. Frequently, the noninfected cysts are mistaken for abscesses; Baumgartner[13] reports four such cases.

REPORT OF CASES.

The following seven cases are reported in the order of their location:

CASE 1.—J. V., male, age 10 years, gave a history of having an intermittent draining sinus in front of the left ear for five years, with resulting swelling, pain, and tenderness upon cessation of the discharge. Examination revealed a fistulous tract about 1 cm. deep anterior to the left tragus, which was discharging pus. Further physical and laboratory examinations were negative. A diagnosis of infected branchial cyst was made. On October 26, 1934, at the Los Angeles County General Hospital, the patient was operated upon, and a cyst 1½ x 2 cm. in size, with four small blind fistulous diverticulæ leading from it were found and dissected out. Pathologic examination showed squamous epithelial lining with muscle and connective tissue in the outer part of the wall. Pathologic diagnosis: branchial cyst. Recovery was uneventful.

CASE 2.—J. C., female, 27 years of age, gave a history of swelling in front of the left ear, slightly over the tragus, which had been present since birth. There had been intermittent drainage from the opening for several years. The patient

stated that her mother and brother had similar openings in the pre-auricular region but they had never shown other symptoms. Examination showed a red, semi-firm, pre-auricular swelling just above the tragus in the center of which was a small dimple like formation in the skin. Further physical and laboratory examinations were negative. A diagnosis of branchial fistula was made. At operation on April 4, 1935, at the Los Angeles County General Hospital, the sac, containing three pockets, was dissected out. Pathologic diagnosis: branchial fistula. The patient was discharged from the hospital in three days and a discharge from the wound occcurred for ten days.

CASE 3.—J. B., female, 63 years of age, gave a history of a swelling of three or four months' duration, beginning back of the right mandible, under the lobe of the ear. The swelling increased in size and pushed forward in front of the ear and over the mandible. One month prior to my examination, this cyst had been opened by a surgeon, and a large amount of serous fluid obtained. The mass completely disappeared for a short time, then began to increase in size, causing pain over the entire side of the face. Examination revealed a swelling about 8 x 5 cm. It was firm and tender only at the margins, non-fluctuating, freely movable, with no attachment to the angle of the mandible. It displaced the lobe of the ear upward. Other physical and laboratory examinations were negative. A diagnosis of branchial cyst was made.

On November 5, 1934, at St. Vincent's Hospital, an incision was made parallel to the zygoma, back to the lobule of the ear, then downward over the tumor to the neck. The lower and anterior borders of the tumor were located and the tumor shelled out. A pedicle was found going around back of the mandible, which was traced almost to the pharynx. Pathologic examination showed a thin and fibrous walled cyst with an opaque, velvety inner surface, 5 cm. in diameter, containing yellow puriform fluid. The inner surface of this fibrous wall was densely infiltrated by an inflammatory exudate and covered by stratified epithelium. Pathologic diagnosis: branchial cyst. The patient was discharged eleven days after operation with a healed incision.

CASE 4.—L. B., male, age 28 years, gave the history of a recent sore throat, more pronounced on the right side, with accompanying enlargement of the cervical glands on that side. On examination, purulent material could be freely expressed from a large tonsil tag at the base of the right fossa. Externally, there was a smooth swelling, the size of a walnut on the same side in front of the sternomastoid muscle, which was thought to be a gland, as several glands of the anterior group were enlarged. Further physical and laboratory examinations were negative. The tonsil tag was removed, after which the smaller glands disappeared and the larger one reduced in size. Two weeks later it began to enlarge and took on the characteristics of a cyst. A diagnosis of branchial cyst was now made.

On August 22, 1934, at St. Vincent's Hospital, an incision was made over the tumor which lay anterior to the sternomastoid. The tumor was shelled out from its bed. A pedicle which was attached to it was traced to the infratonsillar fossa. Pathologic examination showed a unilocular cyst 4.5 x 6 cm. in diameter, containing a viscid, opaque yellow fluid, with a wall 2 to 3 cm. in thickness. The lining of the wall was of stratified, squamous epithelium beneath which was deposited many nodules of hyperplastic lymphoid tissue. Pathologic diagnosis: branchial cyst. The patient was discharged four days later. Recovery was uneventful.

CASE 5.—M. N., female, 35 years of age, gave a history of a small swelling on the left side of the neck of several weeks' duration, not preceded or accom-

panied by a cold or sore throat, and not painful or tender. Examination disclosed a swelling 3 x 5 cm. in the left anterior cervical region in front of the sternomastoid muscle. Other physical and laboratory examinations were negative. During an observation period of eight weeks, the size of the swelling gradually increased. A diagnosis of branchial cyst was made.

On March 15, 1935, at St. Vincent's Hospital, a transverse incision was made through the skin and platysma muscle; the cyst was easily located just anterior to and under the sternomastoid, and a pedicle was found which ran toward and almost reached the pharyngeal wall. The cyst was enucleated, the pedicle ligated with catgut very close to the pharynx and the wound closed without drainage. Pathologic examination showed a unilocular cyst with a white, opaque lining, with fine, granular surface. Microscopically, the cyst was composed of a fibrous layer covered by squamous epithelium internally, with considerable degeneration and multinucleated phagocytes present on the surface and infiltrating the fibrous stroma. Pathologic diagnosis: branchial cyst. Recovery was uneventful.

CASE 6.—R. B., male, age five years. Four years ago the boy's mother first noticed a small hard lump in the midline of the neck under the chin. This lump was lanced by a physician and discharged a mucoid material. Three surgical attempts to remove the draining area were unsuccessful. Examination showed a small opening in the midline, 2 cm. below the chin, 1 mm. in diameter, draining a viscid material. Further physical and laboratory examinations were negative. A diagnosis of thyroglossal cyst was made. On December 13, 1934, at the Hospital of the Good Samaritan, the fistulous tract was dissected to the hyoid bone, the central section of the hyoid bone removed, and the fistula followed to the base of the tongue. The wound discharged for three weeks and then healed completely.

CASE 7.—L. E., female, age nine years, was admitted to the Los Angeles County General Hospital on April 8, 1935, complaining of having a painful tumor in the midline of the neck, just below the larynx. Her parents stated that she had had a small dimple in that region since birth, which intermittently would become swollen, and discharge a thin, serous fluid. On physical examination a tumor mass was found in the midline of the neck, just below the hyoid cartilage, measuring about 1½ x 3 cm. It was fluctuant and slightly tender on palpation. Other physical and laboratory examinations were negative. A large aspirating needle was inserted with the view of aspirating the fluid and injecting lipiodol for x-ray examination. The content of the cyst was so thick, however, that it could not be aspirated. A diagnosis of thyroglossal cyst and fistula was made.

At operation on April 10, 1935, the cyst was found to contain a thick, yellow mucoid substance and the lining was extremely thick. The cyst and fistulous tract was dissected out. The wound discharged for two weeks, after which it healed and the patient was discharged from the hospital.

In a series of twenty cases recorded at St. Vincent's Hospital in Los Angeles during the past ten years, thirteen were diagnosed as originating from the branchial apparatus, and seven from the thyroglossal duct. The occurrence in the sexes was equal and the age incidence was from 3½ to 63 years. Those of branchial origin showed no predilection for either side of the neck. Ten were cysts without fistulas; two were cysts with internal openings, and one a cyst with

an external opening. Three had had previous surgery; 90 per cent were diagnosed before operation.

TREATMENT.

It is generally conceded that complete surgical resection of the entire cyst and its fistulous tract, if it has one, is the only method of treatment that has proven satisfactory. Fistulas must also be removed in their entirety. McNeill Love[14] advocates, in this type, a simple procedure of encircling the orifice of the fistula with a fine purse-string suture. This is inserted as close to the orifice as possible and tightened so as to close the opening. In a few days continued secretion distends the fistula, transforming it into a cyst, which thus facilitates dissection.

Orientation as to the extent of the involved tract may be accomplished by the injection of methylene blue or other color substances, in the manner outlined by Baumgartner.[13] After determining with a probe the direction of the tract, avoiding too great pressure, methylene blue is injected, using a blunt needle. The methylene blue is then thoroughly washed out, thus preventing soiling of the adjacent tissues during surgery from an excessive amount of dye remaining in the tract.

Branchial cysts frequently have a pedicle which must be removed with the cyst, involving at times extensive dissection. Too much stress cannot be placed upon the importance of not rupturing the cysts, with or without fistulas, during removal, as dissection after their collapse is very difficult.

In the removal of thyroglossal duct cysts the tract is always in such close relationship to the hyoid bone that it is necessary to sever the hyoid or take a section out of it in order to effect a complete dissection. The duct is tied and resected at the foramen caecum. The method of Sistrunk[15] is probably the best.

Cutler and Zollinger[16] reported the use of a modification of Carnoy's Solution in a few cases with good results; yet I hardly think that it has been used in enough cases or over a long enough period of time to warrant the displacement of surgery.

SUMMARY.

From the foregoing review of cases and literature it seems to me that branchial and thyroglossal duct cysts and fistulas may be considered, at least in part, laryngologic subjects.

1136 West Sixth St.

BIBLIOGRAPHY.

1. Keith, Sir Arthur: Human Embryology and Morphology. Wm. Wood & Co., 1933.

2. Andrews, E. Wyllis: Keen's Surgery, Vol. III, 278.

3. Bailey, Hamilton: The Clinical Aspect of Branchial Cysts. Brit. J. Surg., x, 565, 1922-1923.

4. Hyndman and Light: Branchial Apparatus. Arch. Surg., xix, 410, 1929.

5. Carp, Louis: Branchial Fistula, Its Clinical Relation to Irritation of the Vagus. Surg., Gynec. & Obst., xlii, 772, 1926.

6. Thomson, J. W.: A Case of Branchial Cyst. Lancet, ccxii, 76, 1927.

7. Coplin, W. M. L.: Branchial Cysts and Fistulas. Proc. Path. Soc., Philadelphia, 4:109, 1900.

8. Virchows u. Hirsche: Dissection of a Congenital Hydrocele of the Neck. Jahresbericht, 1:280, 1882; quoted by Pranesk.

9. Kleinert, Margaret N.: Branchial Fistula. Arch. Otolaryngol., xviii, 510, 1933.

10. Klingenstein, Percy, and Colp, Ralph: Congenital Cysts and Fistulas of the Neck. Ann. Surg., lxxxii, 854, 1925.

11. Wagensteen, O. H.: Differentiation of Branchial from Other Cervical Cysts by X-ray Examination. Ann. Surg., xciii, 790, 1931.

12. Hitz, John B.: Sublingual Epithelial Cyst. Report of a Case. Arch. Otolaryngol., xxi, 338, 1935.

13. Baumgartner, Conrad J.: Branchial and Thyroglossal Duct Cysts and Fistulas in Children. Surg., Gynec. & Obst., lvi, 948, 1933.

14. Love, R. J. McNeill: A Simple Method of Dealing With Congenital Fistulæ. Lancet, ii, 122, 1929.

15. Sistrunk, W. E.: Thyroglossal Duct. Ann. Surg., lxxi, 121, 1920.

16. Cutler, E. C., and Zollinger, Robert: The Use of Sclerosing Solutions in the treatment of Cysts and Fistulæ. Amer. J. Surg., xix, 411, 1933.

LXIV.

THE SPHENOID SINUS AND THE SPHENOPALATINE GANGLION AS FACTORS IN SO-CALLED ATYPICAL TRIGEMINAL NEURALGIA.*

H. W. Lyman, M. D.,

St. Louis.

Tic douloureux, or trigeminal neuralgia, is a definite clinical entity, characterized by intermittent paroxysms of intense pain limited to the distribution of the fifth nerve. These paroxysms are usually induced by the slightest stimulation of a so-called trigger zone somewhere in the distribution of that nerve. For these cases, resection of the sensory portion of the posterior root of the Gasserian ganglion affords the only method of securing complete and permanent relief.

However, the term "trigeminal neuralgia" is often used in describing any severe pain in the face, and variations from the typical tic douloureux, either in the distribution of the pain, or character of the attacks, is accounted for by calling them "atypical trigeminal neuralgias."

In this group of so-called atypical trigeminal neuralgias there are probably a number of different pathologic conditions, either in conjunction with true tic douloureux, or entirely independent of that clearly marked affliction.

When posterior root resections are done in these atypical cases varying results are obtained. In some there is no relief; in others, partial or temporary amelioration of symptoms follows; and in still others, the pain is more intense than before. Cervical sympathectomy (usually of the superior cervical ganglion) is also frequently recommended in these atypical cases.

Frazier[1] reports ten selected cases from a series of thirteen such operations performed in his service at the University Hospital.

The operator excised the superior cervical sympathetic ganglion, and, in some cases, also the middle ganglion and the intervening trunk, and stripped the peri-arterial plexus from the common caro-

*Presented at the meeting of the American Laryngological Association, May 31, 1935, at Toronto, Ontario.

tid artery from a point 2.5 cm. below the bifurcation to 2 cm. above on the external carotid artery. He says:

> Of this series, the sensory root operation in five instances had been performed, and, in all but one of these, no doubt there had been an error in diagnosis. The patients probably did not have true trigeminal neuralgia. The records of this series speak for themselves. In only one case did the patient obtain any relief, and, in this case, there remains the doubt as to whether the relief was permanent, as the patient cannot be traced.
>
> These observations, if accepted, demonstrate rather conclusively that if patients continue to have discomfort after the major operation for trigeminal neuralgia, an operation on the cervical sympathetic ganglion does not offer any hope of relief.
>
> Furthermore, the operation is equally ineffective in that group of painful syndromes which, for want of a better term, I have been in the habit of calling "Atypical Neuralgias."
>
> That one of the patients was entirely relieved by Christian Science suggests a functional rather than an organic basis for the pain, and one may have to be content to view the condition as of psychogenic origin, and discontinue any effort to modify or relieve it by physical procedures.

While it is quite possible that some of these cases grouped as atypical trigeminal neuralgia may be purely psychic, as suggested by Frazier and many others, my own opinion is that in many instances the so-called neurotic state of the patient has an underlying cause, whether we are able to discover it or not, and in the disease we are considering, the so-called neurosis may well be the effect of the prolonged and intense suffering, and the many unsuccessful surgical procedures attempted, rather than the cause of that condition.

Greenfield Sluder,[2] as early as 1908, called attention to a set of neuralgic phenomena that in his opinion were produced by lesions affecting the sphenopalatine ganglion.

In 1919,[3] after an observation of several hundred cases, he described the neuralgic syndrome as follows:

> A short time after an upper respiratory infection, of slight or great intensity, the pain began at the root of the nose, in and about the eye, the upper jaw and teeth (sometimes the lower jaw and teeth) and extending backward to the temple and about the zygoma to the ear, making earache; emphasized at the mastoid but always severest at a point 5 cm. back of that; thence reaching backward by way of the occiput and neck, it may extend to the shoulder blade and shoulder and in severe cases to the arm, forearm, hand, and even the fingertips.

In the same volume he reports several cases which he diagnosed as tic douloureux with sphenoiditis which were relieved by cocainization of the sphenopalatine ganglion. In some of them he later injected the ganglion with 5 per cent phenol in 95 per cent alcohol, and in others he exenterated the sphenoid and ethmoid cells. He mentions

one case in which relief was obtained for four years and then the pain recurred, and a resection of the Gasserian ganglion was done. He also mentions several cases in which the constant sinus pain was anterior to the ganglion and the tic seemed to involve the vidian nerve. Some of these were probably so-called atypical trigeminal neuralgias; but in 1916 he reported[5] two cases which he believed to be true tic douloureux, and which he thought were due to an acute inflammation of the sphenoid sinus, and which were cured by the clearing up of that inflammatory process. The pain was of the sharp, stabbing, recurrent type of tic douloureux, rather than the aching type of longer duration, which usually characterizes sphenoiditis.

In one of these cases the pain ran through the upper jaw, around the eye, backward under the zygoma to the ear, and from there backward and downward into the shoulder. This distribution of pain is that which he describes as due to irritation of the sphenopalatine ganglion. The attacks were brought on by movements of the head.

In the other case, the pains were of the same type, characteristic of tic douloureux, but limited sharply to the distribution of the second and third divisions of the fifth nerve. This case complies with all the requirements of a typical tic douloureux.

He says:

> There are some statements in our literature, more or less at random, attributing the sinuses of the nose as the etiologic factor of tic douloureux, but a record of such perfectly well-defined cases as these that I describe is unknown to me.

In May, 1916, he presented before the American Laryngological Association drawings of anatomic specimens in which the Gasserian ganglion was in close contact with the sphenoid sinus, and offered this as an explanation of why semilunar ganglion neuralgias and tic douloureux of sphenoidal origin sometimes recover if the spenoidal lesion can be controlled.

Cushing[5] gives the following classification of cases which may be mistaken for tic douloureux:

1. Neuralgias accredited to the sphenopalatine ganglion (Sluder's neuralgia).
2. Post zoster neuralgias.
3. Neuralgias accredited to the geniculate ganglion.
4. Painful tic convulsif.
5. Neuralgias from tumor involvement.
6. The minor trigeminal neuralgias.

Concerning the last classification, he says:

> They may follow injuries, particularly when nerves have been contused, or more seriously damaged. They are particularly common as the aftermath of dental procedures. * * * Again, extension of nasal infections to the accessory sinuses is a common precursor of neuralgia, due, unquestionably, to some inflammatory involvement of the adjacent nerve trunks.
>
> * * * Oftentimes, it must be confessed, conditions which we have placed in the category of minor neuralgias are regarded by the patients themselves as most intolerable; but we have done so for the reason that only a single division has been involved and in due consideration it has seemed unwise to perform a Gasserian operation even when intense pain is complained of. When some definite irritative lesion is found, one may look with more or less equanimity on these local neuralgias, but in cases in which the initial paroxysm, unrelated to any discoverable cause, strikes unannounced, and others tend to follow, one must realize that these attacks may be the precursors of the major type of neuralgia.

Concerning the neuralgias accredited to the sphenopalatine ganglion, he believes they should be capable of differentiation from true tic douloureux, by the history or presence of sinus infection, by their frequent bilaterability, by their situation and tendency to radiate to the neck and shoulder, and by their more or less continuous pain, which is not inaugurated by stimulation of a "trigger zone." He describes such a case in which section of the posterior root of the fifth nerve gave no relief, but also cites a case of supposed sphenopalatine neuralgia in which the Gasserian operation resulted in a cure of the trouble.

He believes there is a type of neuralgia conforming to Sluder's description, which, however, he is inclined to attribute to irritation of the maxillary nerve rather than to the sphenopalatine ganglion. Because of the failure to obtain relief in this type of case by the Gasserian operation, he feels that a careful segregation of these cases should be made.

None of the cases I have seen comply with all the requirements for the diagnosis of true tic douloureux. However, I believe the cases here reported demonstrate that posterior sinus infections, with a consequent irritation of the sphenopalatine ganglion, either in connection with, or independent of, tic douloureux, explain some of these cases so loosely grouped together as atypical trigeminal neuralgia.

My attention was forcibly directed to this relationship, in 1923, by the case of a man, fifty years of age, who suffered from severe typical attacks of tic douloureux for four and one-half years. In addition to these attacks, he had constant severe pain in the retromastoid and occipital regions on the same side. Before the posterior root of the Gasserian ganglion was resected, I opened his right sphe-

noid. This relieved the pain in the back of his head, but had no effect on the paroxysmal pain of the tic douloureux, which, however, was completely abolished by the posterior root resection. Evidently, in this case, the patient was suffering from two separate conditions, and both operations were necessary to relieve him.

In addition to the case mentioned, I wish to present the records of several other representative cases of so-called atypical trigeminal neuralgia in which relief was obtained by operation on pathologic sphenoids and ethmoids, and by the injection of the sphenopalatine ganglion with 5 per cent phenol in 95 per cent alcohol. These cases were referred to me through the kindness of Dr. R. M. Klemme, for the study of this problem.

REPORT OF CASES.

CASE 1.—S. R., white, female, age 54 years. On August 27, 1931, this patient had a posterior root resection for trigeminal neuralgia. The fibres of the second and third division were severed, and the first division and the motor root preserved.

Her history was that of a typical tic douloureux of the second division.

She was free from pain after this operation.

In November, 1932, she complained of pain over the right eye, forehead, and "in her nose." This had continued at intervals, and recently it had become almost constant. This pain was repeatedly relieved by cocainization of the right sphenopalatine ganglion, but the relief was only temporary.

On December 12, 1933, the right sphenopalatine ganglion was injected with one-half c.c. 5 per cent phenol in 95 per cent alcohol, and the right sphenoid and ethmoids were opened freely. The tissue removed was sent to the laboratory and reported as showing chronic inflammation. The patient was promptly relieved of her pain, showing that the ganglion injection had been successful, and that the pain was not due to a tic douloureux of the unsevered first division of the fifth nerve.

CASE 2.—M. B., white, female, age 40 years. This patient gave a history of pain of five years' duration. This pain was at first intermittent, later becoming constant. It involved the right maxillary and mandibular regions, and radiated to the lower temporal, aural, and occipital regions. It also involved the back of the neck. The patient also described paroxysms of typical tic douloureux. In fact, she had such an attack in Dr. Klemme's office.

In May, 1932, she had a posterior root resection of the fifth nerve, including the fibres of the second and third division. This relieved a great deal of the pain, but she continued to have severe pain in the region of the right eye, the zygomatic, aural, and mandibular regions. This pain, except that in the lower jaw, was relieved on several occasions by cocainization of the sphenopalatine ganglion.

In September, 1932, under twilight and local anesthesia, the sphenopalatine ganglion was injected with one-half c.c. of 5 per cent phenol in 95 per cent alcohol. The middle turbinate was resected, the posterior ethmoid cells exenterated, and the sphenoid opened. The sphenoid showed little gross pathology, but the ethmoids were filled with polypoid material.

The pathologic report was chronic inflammation of the ethmoid cells.

The patient was relieved of all of her pain except that along the lower jaw.

On March 14, 1933, she had a resection of the right sympathetic trunk below the superior cervical ganglion for this condition, by which procedure the pain in her mandible was relieved.

The pain in this case extended beyond the limits of the fifth nerve and had the characteristics of a sphenopalatine ganglion irritation, due to inflammation of the posterior sinuses. This in addition to the true tic douloureux. The relief was prompt, showing that the sphenopalatine ganglion injection was successful. However, injection of the ganglion had no effect on the pain in the lower jaw.

This patient later developed a glossopharyngeal neuralgia, for which the ninth nerve was severed in the posterior fossa, on April 2, 1935, with relief from pain.

CASE 3.—L. M., white, female, age 61 years. She gave a history of left facial tic, involving both eyelids, beginning in 1914, with gradual increase. She had no pain at that time.

In March, 1916, she had an attack of influenza. Severe headaches began the following summer. At this time the apices of both lungs were dull, and the patient gave a positive tuberculin skin reaction.

In 1921, the attacks of pain had become more frequent and more severe, and the pain was now constant over the left side of the face and down to the left shoulder. The left eyelids twitched constantly. The patient believed that the facial twitching induced the attacks of pain. This case was diagnosed as tic douloureux, but the diagnosis was not concurred in by the neurosurgeon.

The tubercular process was quiescent at this time.

I first saw the patient in September, 1932, at which time she complained of severe pain above both eyes, and on both sides of the head and neck. Much worse, however, on the left side. Because the pain could be controlled by cocainization of the sphenopalatine ganglion, and because the posterior sinuses on the left side showed evidence of infection, on September 27, 1932, the left sphenopalatine ganglion was injected with one-half c.c. of 5 per cent phenol in 95 per cent alcohol, the left sphenoid was opened, and a large amount of pus released. The mucous membrane was greatly thickened. The posterior ethmoid cells were opened and also showed greatly thickened mucous membrane. The pathologic report was chronic inflammation of the sphenoid and ethmoid. Cultures from the sphenoidal pus showed a profuse growth of streptococcus veridans and a scanty growth of hemolytic staphylococcus albus.

The relief in this case was prompt, indicating a successful injection of the ganglion, and her chief complaint thereafter was the twitching, due to the seventh nerve tic. However, she has had several reinfections of her sinuses, and, with each attack of sinusitis there has been a return of the pain, more or less severe, but never as bad as before the operation.

This case illustrates the fact that frequently the effects of alcoholic injection of the ganglion are only temporary, and pain can later be excited by irritation of the revivified ganglion.

CASE 4.—J. M., white, male, age 28 years. Since the age of twenty-one, the patient has complained of severe headaches, especially on the left side of the face. There was increased nasal discharge and the eye became red. The pain spread over the side of the head and back to the left occiput. Attacks sometimes lasted for

two hours. Cocainization of the sphenopalatine ganglion relieved these attacks. The left sphenoid was irrigated and thick mucopus washed out of the sinus.

On April 27, 1934, the left sphenopalatine ganglion was injected with 5 per cent phenol in 95 per cent alcohol, and the left sphenoid and ethmoids opened. Pus was found in the sphenoid, and the lining membrane of both the sphenoid and ethmoid cells was thickened and showed a chronic inflammatory process. The relief from pain in this case was prompt, indicating a successful injection of the ganglion.

On June 25th he had a severe attack of pain, and the left ethmoid cells were found to be acutely inflamed. Subsequent to this time his attacks of pain varied with the condition of his sphenoid sinus. These sphenoid infections usually responded to treatment, but in March, 1935, he had an attack of pain, and this time the sphenoid infection did not respond to treatment as readily as it had previously. On March 10th the sphenopalatine ganglion was again injected with 5 per cent phenol in 95 per cent alcohol, which promptly controlled the pain, in spite of the presence of the sphenoiditis. His sinuses at the present time appear to be in good condition and he is free from his pain.

In this case, while the attacks of pain came on in paroxysms, they lasted longer than a typical tic douloureux, and the pain extended beyond the distribution of the fifth nerve. While the alcoholic injection of the ganglion gave immediate relief, this effect wore off in two months, although the attacks of pain were not as disabling as they had been before the operation. The second injection of the ganglion again gave prompt relief. This patient was also markedly allergic, but there was never any difficulty in distinguishing between the effects of his allergy and the neuralgic condition.

Case 5.—J. B. C., white, male, about 55 years of age. In 1929 this patient complained of severe paroxysms of pain in the left side, centering in the left eye and spreading to the face, vertex and occiput. These attacks usually came on in the night and lasted twenty-five to forty-five minutes. During these attacks the conjunctiva of the left eye became intensely injected. The attacks persisted for about six weeks and then were followed by an interval of freedom from pain for about the same length of time. The patient stated that the attacks were more severe if he was worried.

At this time, and again in 1931, a diagnosis of trigeminal neuralgia was made, and resection of the posterior root of the Gasserian ganglion was recommended, although neither the distribution of the pain nor the duration of the attacks were characteristic of tic douloureux.

In January, 1933, he was examined elsewhere and the sinuses were said to be normal. Resection of the superior cervical sympathetic ganglion was advised.

I first saw this patient in April, 1933. Cocainization of the left sphenopalatine ganglion promptly stopped several of the attacks. May 1st, x-ray plates of the sinuses were made, after the displacement instillation of lipiodol by Proetz' method. Ninety-six hours later, lipiodol was still present in the left sphenoid and left posterior ethmoid cells.

May 5th, one-half c.c. of 5 per cent phenol in 95 per cent alcohol was injected into the region of the left sphenopalatine ganglion, and the left sphenoid and ethmoid cells were opened. The frontal sinus, at this time, was open and a probe could be easily passed into that sinus.

The pathologic report was chronic inflammation of the mucosa of the sphenoid and ethmoid.

The relief from pain was not prompt in this case, the reason probably being that the alcoholic injection did not reach the ganglion, the needle having been introduced too low.

May 11th, he contracted a severe upper respiratory infection, and on May 20th had severe attacks of pain. At this time the left sphenoid could be seen filled with pus. As the sinusitis cleared, under treatment, the attacks of pain diminished and finally cleared up.

July 31st, he complained of pain above the left eye, but no occipital pain. This appeared to be due to obstruction of the left frontal sinus.

September 11th, he complained of pain in the left occipital region and left arm. At this time the left sphenoid was again full of pus. This cleared up promptly after washing out the sphenoid with weak ephedrin-saline solution.

During the winter his pain fluctuated with the condition of his sinuses.

In March, 1934, he had a series of attacks of very severe pain over his left eye, accompanied by a mucopurulent discharge from his left frontal sinus. The severity of the pain was probably aggravated by a profound psychologic disturbance, and, because of this condition, it was not deemed wise by his physician to enlarge the opening into the left frontal sinus at this time.

The failure to obtain prompt relief in this case was because the injection of the ganglion was probably unsuccessful, but relief did follow the clearing up of the spheno-ethmoiditis, with relapses occurring with each re-infection of those sinuses. The pain caused by inflammation of his frontal sinus was distinct in character and distribution from that due to the sphenoiditis.

This paper is simply a clinical study in which an attempt has been made to separate from the heterogeneous mass of atypical trigeminal neuralgias a group of cases having a definite pathology and a recognizable symptomatology.

The cases in which the ganglion injection was successful obtained almost immediate relief, but if the injection was unsuccessful, the relief came on more slowly, as the sinusitis, which was responsible for the irritation of the ganglion, cleared up. It was attempted in each case because, if successful, the relief was so prompt.

The described procedure has not been undertaken in any case in which cocainization of the sphenopalatine ganglion failed to relieve the pain.

Whether this syndrome is due to irritation of the sphenopalatine ganglion by the inflammatory process in the sphenoid and posterior ethmoids, as believed by Sluder, or is due to irritation of the vidian nerve, as suggested by Vail,[6] must be left to the anatomists and physiologists to answer. When our knowledge of the structure and functions of the complicated nerve supply of the head and neck becomes sufficiently complete, this, as well as the many other puzzling

phenomena of atypical neuralgias can be accurately and scientifically solved. Until such time, physiologic hypotheses, based on clinical observation and our present incomplete knowledge of these structures in the human being, will often be proven inaccurate and even false. However, this should not deter us from using every facility at our command for the relief of our patients suffering from these afflictions.

CONCLUSIONS.

1. "Atypical trigeminal neuralgia" is a term loosely used to describe a number of different pathologic conditions, which are not true tic douloureux.

2. These cases are not relieved by the Gasserian operation.

3. Cervical sympathectomy also usually proves inadequate.

4. Among these so-called "atypical trigeminal neuralgias" are some in which the character of the attacks and the distribution of the pain correspond to the sphenopalatine neuralgia described by Sluder. This condition may exist in conjunction with true tic douloureux or independently of that condition.

5. If we can recognize this condition and remove the cause of the ganglion irritation, we can relieve these patients of their pain and spare them the ordeal of an unnecesary and unsuccessful Gasserian operation.

6. If the pain can be controlled by cocainization of the sphenopalatine ganglion, the free opening of the adjacent, infected sinuses, either with or without the injection of the sphenopalatine ganglion with 5 per cent phenol in 95 per cent alcohol, offers a rational and successful method of treatment.

CARLETON BLDG.

BIBLIOGRAPHY.

1. Frazier, Charles H.: "Atypical Neuralgia." Arch. of Neur. and Psych., 19:650 (April), 1928.

2. Sluder, Greenfield: "The Role of the Sphenopalatine Ganglion in Nasal Headaches." New York Med. J., May 23, 1908.

3. Sluder, Greenfield: "Headaches and Eye Disorders of Nasal Origin." C. V. Mosby Company, 1919.

4. Sluder, Greenfield: "Two Cases of Tic Douloureux of Sphenoidal Inflammatory Origin." Laryngoscope, February, 1916.

5. Cushing, Harvey: "The Major Trigeminal Neuralgias and Their Surgical Treatment." A. J. Med. Sc., August, 1920.

6. Vail, H. H.: "Vidian Neuralgias from Diseases of the Sphenoid Sinus." Arch. of Surg., 18:1247-1255.

LXV.

DIFFERENTIAL DIAGNOSIS OF ENLARGEMENT OF THE LYMPH GLANDS OF THE NECK.*

R. F. FARQUHARSON, M. B., F. R. C. P. (C),

TORONTO.

Enlargement of the lymph glands of the neck may be classified in several different ways. For purposes of this discussion, the following classification is suggested:

Local Enlargement

1. Lymphadenitis secondary to infection, as: in tonsillitis, pharyngitis, herpes, aphthous stomatitis, furuncles of head, face and neck, infected abrasions of face, scalp and neck.
2. Tuberculous adenitis (rarely generalized).
3. Early Hodgkin's disease.
4. Lymphosarcoma (rarely generalized).
5. Secondary carcinoma (primary in face, head, neck, nose, sinuses, larynx and stomach).

Generalized Enlargement

1. German measles.
2. Syphilis.
3. Infectious mononucleosis.
4. Lymphoid leukemia—acute, chronic.
5. Advanced Hodgkin's disease.

LOCAL ENLARGEMENT.

Lymphadenitis secondary to infection. Enlargements of cervical lymph nodes in response to local infection usually present little difficulty in diagnosis, especially when the primary lesion is acute. Everyone is familiar with the tender swelling of glands that occurs in patients suffering from furuncles, herpes, aphthous stomatitis, and acute tonsillitis and quinsy. Usually the swollen glands are discrete,

---

*Read before the annual meeting of the American Laryngological, Rhinological and Otological Society, Inc., Toronto, 1935.

From the Department of Medicine, University of Toronto, and Toronto General Hospital.

seldom very large, almost always tender, often associated with periadenitis and slight inflammatory edema, and rarely of importance. They disappear when the acute infection subsides. Occasionally in scarlet fever and other acute streptococcic infections a more severe adenitis arises, the glands are larger, exquisitely tender and frequently fused in an inflammatory mass that may suppurate and require incision. The patient is ill, with high fever, general weakness and sometimes acute hemorrhagic nephritis. The acute character of the lesion makes the diagnosis obvious. The primary lesion may be insignificant, especially if in the scalp, but a careful examination of the area drained by the enlarged tender gland will reveal the source of the infection.

In the presence of subacute or chronic inflammation and in patients suffering from recurrent acute infection, especially of the tonsils, the regional lymph glands are often slightly enlarged, fairly firm, discrete, definitely outlined, either not tender or only slightly tender. Such glands give little trouble in diagnosis, but their presence is evidence of the local disease and an indication for tonsillectomy.

Tuberculosis. Tuberculous adenitis is perhaps the commonest cause of gross chronic enlargement of the cervical lymph glands. Frequently one of the easiest diagnoses to make, it may at times be distinguished with difficulty from a low grade septic infection on the one hand, and from Hodgkin's disease or lymphosarcoma on the other. Children and young adults are most commonly affected, and especially in districts where the milk is not pasteurized. Characteristically, it begins in the glands at the angle of the jaw on one or both sides, the tonsils being the portal of entry. Increase in size is slow and for some time the patient may be quite unaware of the disease. It commonly extends to the submaxillary and superior deep cervical glands and later to the inferior deep cervical glands. It may be localized for long periods, remaining inactive and inconspicuous. With increasing activity, larger swellings appear, usually the greatest mass being at the angle of the jaw with enlarged glands of gradually decreasing size and varying consistency forming an irregular chain down the neck. The glands at this stage are tender and the patient suffers from malaise, fatigue and low fever. There is periadenitis with a certain amount of inflammatory edema which renders the outline of the gland indistinct and gives rise to matting together of adjacent glands and groups to form irregular masses of varying size. The inflammatory process may go on to softening and suppuration with involvement of the skin and ultimate breaking down and sinus formation. More frequently healing occurs and the swelling may subside

to become imperceptible, or fibrosis and calcification may occur, leaving definitely enlarged glands, firm to hard, sharply outlined, discrete, not tender, that give rise to no symptoms.

Occasionally, in a patient whose tuberculous adenitis seemed to have been healed for years, the inflammation may suddenly become acute and even suppurative, resembling subacute septic adenitis. Then history of former disease and absence of primary infection in the area drained are helpful diagnostic features.

Although tuberculous adenitis is most common in children and young adults, it may occur at all ages and sometimes a hard tuberculous gland in old people is mistaken for secondary malignancy. Although it arises usually high in the neck near the angle of the jaw, it may begin and remain localized in the supraclavicular lymph glands, especially those near the head of the clavicle, when the differentiation from Hodgkin's disease may for a time be difficult. At times also it involves chiefly the salivary glands and related adenoid tissue. Then it may be associated with uveal disease, giving rise to the syndrome of uveo-parotid tuberculosis, of which facial paralysis is a common symptom.

Tuberculous adenitis is easily diagnosed when the disease is active with enlarged tender glands, especially when these are high in the neck. There is usually no doubt of the condition when it goes on to suppuration or when it is recurrent. Difficulty arises when, as rarely, it is extremely widely spread or when there is a large, firm, nontender mass, particularly if low in the neck. Then it is to be differentiated from Hodgkin's disease and lymphosarcoma.

Hodgkin's disease. Hodgkin's disease, also referred to as lymphadenoma, lymphogranuloma, or malignant granuloma, is a chronic disease, most typical in adolescence and early adult life, that first manifests itself in enlargement of a local group of glands and later, after weeks, months or years, extends to involve glands in other areas. Most commonly the supraclavicular glands on one side are first involved, but the disease may begin in glands in the postcervicular triangle, in the axilla, infraclavicular region, mediastinum, abdomen or groin. At first the glands are discrete, freely movable, not tender, slightly firm and elastic. It is at this stage that differentiation from tuberculosis may be difficult. Later, they become firmer, may even be hard, and usually adhere to one another to form large masses of semidiscrete glands that are never fixed to skin or deeper structures and rarely, if ever, tender. Frequently, quite a large mass of this type

is to be felt in the supraclavicular area without material enlargement elsewhere; sometimes, on the other hand, groups of elastic, discrete glands with no single large mass anywhere may be felt in several areas by the time the patient seeks medical advice. From the first the patient usually suffers from lack of energy, fatigue, mild malaise, some loss of weight and low fever. Not infrequently distressing pruritis is an early symptom. Occasionally the temperature is moderately high and sometimes there are periodic bouts of fever lasting seven to fourteen days, associated with aggravation of the general symptoms which abate in the interval. Early in the disease there is little or no anemia, although the patient is often pale. Later, a secondary anemia of moderate degree develops. At first the white blood count is normal; there is usually a slight relative lymphocytosis, often an increase in endothelial leucocytes, and not infrequently an eosinophilia. In the later stages, the white blood count sometimes rises as high as 15,000 to 20,000—in one instance, in a patient at the Toronto General Hospital, it was 40,000—with a high percentage of polymorphonuclears.

When glands in many areas are involved, the diagnosis is usually easy. Lymphoid leukemia is ruled out by the absence of a high white blood count and the rarer aleukemic leukemia by the absence of a marked lymphocytosis. Sometimes widely spread tuberculous adenitis is confused with Hodgkin's disease and, indeed, many authorities believe that the two diseases frequently exist together. It is in the early stage when the enlarged glands are localized and discrete that greatest difficulty occurs. In Hodgkin's disease, however, the spleen is usually palpable from the first, whereas this is quite an uncommon finding in tuberculosis. Tuberculous glands are commonly tender and this finding at once rules out Hodgkin's disease. Tuberculous adenitis usually begins high in the neck, and Hodgkin's disease almost always low in the neck. Sometimes, however, a group of non-tender tuberculous glands in the supraclavicular region is almost indistinguishable on physical examination from Hodgkin's disease. It is true that tuberculosis tends to affect glands near the head of the clavicle, whereas in Hodgkin's granuloma the masses usually appear well out in the supraclavicular area. One may resort to biopsy, and in most instances the pathologist will be able to differentiate the two conditions. Not infrequently, however, there will still be room for a difference of opinion, and the diagnosis will then be determined by the subsequent course of the disease. In patients suffering from Hodgkin's disease, glands in other areas will become involved, the enlarged glands will disappear quickly under radiation therapy, to return, unfortunately, after a period of several months; and within a few

years the disease will terminate fatally. In tuberculosis, on the other hand, the glands may enlarge further, become tender and even suppurate; usually the disease will not spread to other areas, although the axillary glands may become involved; almost always the inflammatory process will subside, although it may recur even after many years, and very rarely will it be fatal. Occasionally, however, especially in patients suffering from a generalized or miliary tuberculosis, there may be a widely spread tuberculous adenitis with splenomegaly. It is in such patients that the two diseases are believed to exist together. In these relatively rare instances the granulomatous reaction in the glands to the tuberculous disease is of a type very similar to that of the Hodgkin's granuloma.

The clinical manifestations of Hodgkin's disease vary considerably as does its pathologic picture. The more typical cases are found in adolescents and young adults. In older patients it tends to run a more rapid course, often associated with larger local swellings and sometimes with infiltration of neighboring tissues. Should a gland be removed, the microscopic appearance of such tissue may resemble that of lymphosarcoma. In some cases, according to Ewing, there is actually a transformation of Hodgkin's granuloma into a sarcomatous condition which he calls Hodgkin's sarcoma.

Because of the difficulty at times found in distinguishing between Hodgkin's disease, Hodgkin's sarcoma, lymphosarcoma, and similar diseases of lymph glands, many writers have grouped them all together under the term lymphoblastoma, making no attempt at differentiation. The frequent occurrence of borderline cases affords some justification for doing so. There is, however, a very typical picture of Hodgkin's disease with fairly distinctive clinical and pathologic characteristics. It is true that this shades off till it may be indistinguishable from tuberculous adenitis on the one side and from lymphosarcoma on the other. Yet the differentiation is of definite value.

Lymphosarcoma. Typically, lymphosarcoma is a local condition arising from a group of lymph nodes or from adenoid tissue of mucous membranes. Rarely is it generalized. Unlike Hodgkin's disease, it commonly begins in the tonsil or adenoid tissue of the pharynx. There is progressive enlargement of the primary tumor with ulceration and extension to the regional cervical lymph nodes. The spleen is not affected. General malaise and fever do not appear in the early stages and there is no pruritis. The glands subside quickly under radiation therapy but unfortunately the recession is but temporary

and the disease recurs and progresses, usually going on to a fatal termination in from one to five years.

Secondary carcinoma. Cervical glands may be secondarily involved when there is carcinoma of the mouth, tongue, pharynx, larynx, nose and nasal sinuses, ear, face, scalp, pituitary body and stomach. Usually there are but a few palpable glands and these are hard. With further growth they become fixed and ulceration of the skin may occur. Occasionally quite a large mass of malignant glands is found.

In most instances the site of the primary growth is known and the nature of the glandular enlargement is then obvious. Occasionally a large, hard "sentinel gland" above the head of the clavicle, usually on the left side, is a helpful sign of carcinoma of the stomach which formerly may not have been suspected. Sometimes a transitional cell carcinoma (lympho-epithelioma) arises inconspicuously high in the nasopharynx, the enlargement of regional lymph glands being the first evidence of the disease. The primary tumor may be found only after most careful examination; sometimes only by careful palpation in the pharynx. In a few instances secondary carcinoma has been found in cervical glands when it has been impossible to find any primary disease even after most careful investigation. The finding of hard, non-tender cervical glands for which there is no apparent cause is, of course, an indication for excision of a gland and histologic examination of the specimen.

GENERALIZED ENLARGEMENT OF LYMPH GLANDS.

Enlargement of lymph nodes in many areas, as well as in the neck, is characteristic of certain generalized infections, notably, German measles, syphilis and infectious mononucleosis, as well as of lymphatic leukemia and the later stages of Hodgkin's disease and some cases of lymphosarcoma.

German measles. One will seldom have difficulty in recognizing the adenitis associated with German measles. Beginning usually a day or two before the appearance of the rash, sometimes as long as a week before, there is a slight but definite and very widely spread enlargement of all lymph glands. Those in the neck along the posterior border of the sternomastoid and in the mastoid and suboccipital groups, are perhaps most constantly affected and most easily palpable. The glands are small, firm, discrete and usually painless. Occasionally fairly marked enlargement may occur locally. Often the patient is unaware of the glandular swelling until it is drawn to his attention

by the physician; but sometimes the glands are tender and they may give rise to stiffness of the neck before the appearance of the rash explains the nature of the trouble. The glands usually subside as rapidly as they appear, leaving no trace of the disease.

Syphilis. In the secondary or generalized stage of syphilis there is slight, widespread enlargement of lymph glands which are small, firm, freely movable and not tender. They appear coincidently with the characteristic skin eruption and luetic pharyngitis and tonsillitis. Rarely conspicuous, they often remain for some months after the disappearance of other secondary manifestations, then gradually disappear. Their importance is frequently exaggerated, and often in thin people relatively normal lymph glands may be considered as suggestive of luetic disease. The finding of slightly enlarged lymph glands in the occipital region, provided one can rule out German measles and local lesions of the scalp, is, however, suggestive of early luetic infection and demands further inquiry into recent history and serologic investigation.

Lymph gland enlargement in late syphilis is very unusual. Sometimes gumma of the sternomastoid or other tissue may be mistaken for luetic adenitis but on careful examination one will soon recognize the error.

Infectious mononucleosis. Infectious mononucleosis or glandular fever is an infectious disease of unknown etiology that affects children and young adults and, strangely, appears to be particularly frequent in medical students, nurses and young physicians. Usually it begins with malaise, fever, headache, sore throat, and early enlargement of cervical and other glands which are tender. Occasionally the onset is more gradual, tenderness of the enlarged glands being an early complaint. At its height the temperature reaches to between 100 and 104 degrees. There may be marked swelling of the tonsils and adenoid tissue of the pharynx, sometimes with ulceration. The enlarged glands are almost always tender, and the enlargement is usually greatest at the angle of the jaw. Swelling of submental glands is frequently seen, and enlarged glands are usually present in each axilla and often in the inguinal and femoral regions. The spleen is commonly palpable and sometimes tender.

A striking feature of the disease is the increased white count, which may reach 15,000 to 20,000, or higher, in the second week of the disease, with a lymphocytosis usually of over 70 per cent. There is, however, no anemia, no hemorrhagic tendency, no reduction in blood platelets. In the third week of the disease the patient begins

to improve: temperature, pulse and white blood count fall toward normal; the glandular swellings subside and the patient gradually and completely recovers.

The presence of sore throat, fever, generalized lymph gland enlargement, high white blood count, and lymphocytosis naturally lead one to think of acute leukemia.

Acute leukemia. Acute leukemia, whether lymphoid, myeloid or monocytic, is a disease that progresses rapidly to a fatal termination within a few months. It is characterized by a gradual onset with slight weakness, pallor, increasing fever, generalized enlargement of lymph glands and spleen, ulcerative stomatitis and pharyngitis, hemorrhagic tendency, and increasing anemia. The white count is commonly high, but may be normal or even decreased; the great majority of the white cells are immature. The platelets are reduced in number. The gradual onset stands out in contrast to the more abrupt onset of infectious mononucleosis. Angina, an early symptom in glandular fever, is later in acute leukemia. In both, because of the tonsillitis and pharyngeal lesions, the glands at the angle of the jaw are larger than those in other areas and usually tender. In infectious mononucleosis there is no associated anemia, no purpura or hemorrhagic tendency and no reduction in platelets. Should one be in any doubt, a short period of observation will quickly clear the diagnosis; for the patients with leukemia will slowly become worse, whereas those with infectious mononucleosis will improve rapidly in the third and fourth weeks and completely recover.

Chronic lymphoid leukemia. There is no other disease that gives rise to such widely spread multiple enlargement of superficial lymph glands as does chronic lymphoid leukemia. In all areas in the neck—submaxillary, submental, high and low in anterior and posterior cervical triangles, in the occipital and supraclavicular regions—one finds numerous firm, discrete glands, not tender, that vary in size from about two centimeters in diameter downwards. Wherever in the body one looks for lymph nodes, they will be found enlarged. The spleen is always palpable and sometimes quite large. The tonsils and lymphoid tissue of the pharynx are commonly involved.

Such universal enlargement of superficial lymph glands may be quite marked before there is anemia or any definite malaise or weakness. Early in the disease, however, the white blood cells are increased in number, usually to more than 50,000—commonly 100,000 to 200,000, and sometimes much higher. The type cell is a small lymphocyte.

Just as in Hodgkin's disease and lymphosarcoma, there are variations from the typical picture. The white blood count may be normal or but slightly increased, the percentage of lymphocytes being high. Such aleukemic leukemia is, however, quite rare.

Occasionally there is leukemic infiltration of surrounding tissues in a sarcomatous fashion. One may find infiltration of liver, pancreas, pleura or superior mediastinum. In some such cases tracheal obstruction may give rise to severe dyspnea with stridor. Cases in which leukemic infiltration occurs often run a subacute course to a fatal termination within a year. Usually the white blood count varies between 50,000 and 100,000. When seen early, however, the white blood cells may be decreased—an aleukemic phase—but usually the count rises to high figures in the terminal stages of the disease.

As stated earlier, Hodgkin's disease is never so generalized as is chronic lymphoid leukemia. The blood picture serves further to differentiate the two conditions. Only rarely in grossly atypical cases will one have difficulty in distinguishing one from the other.

COMMENT.

The diagnosis of enlargement of cervical lymph glands is usually made without difficulty on history and clinical and hematologic examination alone. Of the swellings affecting only cervical lymph nodes difficulty is sometimes found in differentiating certain cases of tuberculous adenitis from lymphosarcoma and early Hodgkin's disease. A biopsy is often helpful in these circumstances, but unfortunately the histologic picture is not always decisive and the diagnosis may then be determined only by the subsequent course of the disease. In patients with generalized lymph gland involvement, one must be careful not to confuse infectious mononucleosis, which is never serious, with acute leukemia which is always fatal. The differentiation is clearly made by clinical examination and study of the blood picture.

In conclusion, one would stress the importance of history and clinical examination with a consideration of the blood picture. The information obtained by histologic examination of the excised gland is often useful but sometimes indeterminate and occasionally misleading. It should be considered together with all the clinical data in the final summing up of difficult cases.

170 St. George St.

LXVI.

FURTHER STUDY OF THE EFFECTS OF DRUGS ON CILIARY ACTIVITY: A NEW METHOD OF OBSERVATION IN THE LIVING ANIMAL.*

D. M. LIERLE, M. D.,

AND

P. M. MOORE, M. D.,

IOWA CITY.

Several years ago the authors became interested in the immediate direct effects of certain drugs on the speed and continuation of ciliary activity. It seemed desirable to know whether any of the drugs used in the daily treatment of the nose had a deleterious influence on this mechanism. Accordingly, a series of the more commonly used drugs was selected and their effects noted upon (1) the extirpated human mucosa mounted in a special chamber, and (2) the nasal mucosa, in situ, of freshly killed guinea pigs.[1]

It was realized that the conditions under which the observations were made differed considerably from those existing in the noses and sinuses of living animals. Care was taken to keep the tissue at the optimum temperature, to protect it from drying, and to supply it with the proper nourishment. The mucus sheet was largely eliminated by continuous washing with Locke's solution so that the effects noted were due to the simple direct action of the drug upon the cilia, uncomplicated by any variable modifying influences.

After noting the simple reactions of the cilia to the drugs employed, the next step was to see how results might be modified in the living animal. Accordingly, the present work was undertaken and an attempt made to approximate, as nearly as possible, the natural conditions existing in the maxillary sinus in vivo. Although some observations were made upon the live guinea pig, this animal proved unsatisfactory for the study. The successful observations upon the

---

*Presented before the annual meeting of the American Laryngological Association at Toronto, Canada, May 29, 1935.

From the Department of Otolaryngology and Oral Surgery, University Hospital, Iowa City, Iowa.

living rabbit reported by Proetz,[2,3] suggested a suitable subject for the present experiment.

In 1924, J. C. Sandison,[4] working under E. R. Clark, reported the use of transparent windows in the microscopic study of living cells and blood vessels in the rabbit's ear. A number of subsequent publications have given the results of these studies and have recorded certain improvements.[5,6]

It was quite obvious that conditions in the unopened sinus could not be duplicated. Nevertheless, it was felt that the use of the transparent window would come much closer to the normal conditions than any method previously used. This method leaves much to be desired, and it is hoped that some future work will eliminate the shortcomings of the present method. There was no escaping the trauma and shock of a surgical procedure and a certain amount of serous exudate from the cut tissue was unavoidable. It was necessary also to remove the membrane completely from the lateral wall of the sinus, reducing the number of mucus secreting elements and possibly interfering with some of the normal currents of mucus flow.

Two materials were tried for the windows: Glass and pyralin. The glass was much clearer for microscopic observations, but because it offered so little resistance to the passage of light rays, it was difficult to keep it sufficiently warm to prevent fogging on its inner surface, without subjecting the membrane beneath it to too much heat.[7] On the other hand, pyralin scratched easily, and at times revealed the image slightly distorted, but it absorbed heat from the light so readily that it was easily defogged without raising the temperature of the membrane above 97° F.

Because of the low magnification required, the poorer optical qualities of the pyralin did not interfere with the observations. The material used was .025 inches thick, and was cut in oval shape to fit over the opening made in the lateral surface of the maxillary bone. Two holes were bored in each window. When the window was in place, one hole was in an antero-inferior position for the drainage of serum and excess fluids, and the other was in a posterosuperior position for the introduction of drugs. When not in use, both holes were closed with moistened plugs of cotton to check drying and to prevent passage of air and consequent disturbance of air currents.

The rabbits were anesthetized by intravenous injection of 0.3 cc. veterinarian nembutal, per pound of body weight. This gave a deep satisfactory surgical anesthesia. It was necessary to repeat half of

the original dose when the observations extended over more than a two-hour period.

This procedure was followed: The side of the nose was shaved. A longitudinal incision was made over the groove on the side of the nose, just below the nasal bone and the frontal process of the premaxilla. This groove is produced by a large dehiscence in the maxillary bone and is filled with fibrous tissue. The angular vein lies in the middle of the groove. The dissection was carried down to the frontal process of the premaxilla, reflecting the angular vein downward. The fibrous tissue was dissected away from the edges of the bone and lifted off the mucous membrane of the lateral wall of the antrum. If great care is taken, this can be accomplished without tearing the mucous membrane. The membrane next was elevated from the inner surface of the maxilla and the bone removed with rongeurs to the floor of the sinus. All bleeding was controlled carefully before the sinus cavity was opened. When the wound was dry the mucous membrane was removed from the lateral wall of the antrum. No bleeding attended this procedure. The window, already prepared, was inserted beneath the skin and subcutaneous tissues, where it acted as a partial retractor, keeping the skin edges apart. Usually the skin overlapped the edges of the window sufficiently so that the tissue juices sealed it in place, making the cavity air tight again. When this did not take place, the skin was drawn together at one end of the incision with sutures.*

The first three windows inserted were provided with only one hole. This was threaded and could be closed with a brass screw. These windows were left in place. In one instance, there was necrosis of the skin, and the window fell out at the end of three weeks. The skin healed firmly around the other two and held them in place. However, by the end of a month, granulation tissue had grown in beneath the windows from all sides, so that the opening into the sinus had been markedly reduced. One of these windows was removed and the opening carefully enlarged. There was some thick exudate in the sinus. When this was washed out with Locke's solution, active cilia could be seen.

An improved type of window is being developed at the present time which may prevent the encroachment of tissue from the sides, and so provide a permanent transparent inset through which the

*In a very recent work, Lucas and Douglas[8] have used a similar procedure in making observations on the trachea of the turtle, and have tried the transparent window in experiments on ducks.

ciliary reactions can be observed over periods of days or weeks. In the meantime it was decided that observations would be made upon the freshly prepared rabbit to determine the immediate effects of the drugs used, and to record those recoveries which occurred within a relatively short time.

The prepared rabbit was put in a holding box which was placed on a movable stage. (See illustrations.)

Because of the small size of the aperture through which the observations were made, a more compact lighting arrangement than that used on the guinea pigs was required. A Leitz ultrapak illuminator was placed on the microscope and illumination similar to that used by Proetz[2 9 10] was obtained. There were times, however, when the mirror reflection method,[1 11] used previously, gave better results on a given subject. The ultrapak illuminator did not give off sufficient heat to keep the window free from fog, so that when observations were being made the mirror reflection was used from time to time to clear the window.

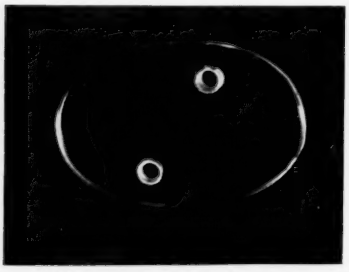

Fig. 1. Transparent window.

The drugs were applied with medicine droppers drawn out to a fine point. The plug in the posterosuperior hole was removed. The tip of the dropper was inserted through the hole until it could be seen in the microscopic field, and one or two small drops of the drug were applied directly to the cilia which had been visualized. Only one application of the drug was made. The hole was plugged again and the immediate effect of the drug was noted. During observations requiring five minutes or less, the area was watched constantly. Those requiring longer periods were noted at regular intervals.

When a drug caused a slowing or cessation of the beat, timed observations were continued until there was a recovery, or until all hope of recovery without regeneration was gone. No washing of any kind was employed. All drugs which were compatible with Locke's solution were placed in it, as in previous experiments. This was done to eliminate any possible slowing due to a water solvent. Those drugs which were incompatible with Locke's were used in aqueous solution.

The tables of results obtained in previous studies are repeated here so that the in vivo observations may be compared with them.

Fig. 2. Window in place.

Fig. 3. Complete apparatus.

The saturated thymol in Locke's solution and the 0.5 per cent silver nitrate were eliminated from the present list of drugs because of their marked toxicity. The 10 per cent solution of the mild silver protein was the only one repeated. Phenyl mercuric nitrate, 1:10,000, was added to the list.

There were some essential differences in the modus operandi of the observations made on the excised tissue, the freshly killed guinea pig, and of those made on the living animal. In the former experiments the tissues were bathed continuously in the drug until a reaction was observed. They were then washed in Locke's solution until recovery took place. In the living animal only one or two drops of a drug were applied and no washing of any kind was done. This latter procedure was used to approximate the application of drugs in the nose, by drops or by spray from an atomizer. The actual use of the spray was not practical during these experiments, because droplets deposited upon the inner surface of the window would have interfered with observations.

TABLE 1.—*Results of Determinations Made in the Chamber*.*

	Effect												
Drug	1	2	3	4	5	6	7	8	9	10	11	12	13
Ephedrine, 3%.....	0	0	0	0	0	0	0	0	0	I 2′	0	I	0
Cocaine, 5%.....	DR	DR	DR	0	0	0	0	0	0	0	DR	0	0
Menthol, 1%.....	DR 2′	DR	DR 2′	0	DR	DR	DR	DR	DR	DR	0	DR	DR 3′
Thymol, 1%.....	SR 1′30″	S 1′30″	DR 40″	DR 30″	DR 30″	DR 40″	DR 30″	S 3′15″	S 3′	S 3′	S 1′15″	S 1′	S 1′15″
Eucalyptol, 1%.....	SR 2′	S	S	S	S 2′	DR	S 3′	S 3′	S	S 3′	S 3′	S 2′15″	S 2′30″
Atropine, 1%.....	DR	0	0	0	0	0	0	0	0	0	0	0	0

* Time five minutes unless otherwise specified. I indicates increase; D, decrease; 0, no change; S, stopped; R, recovery after washing with Locke's solution.

ANALYSIS OF DATA.

In general the reactions were the same. Those drugs which stopped or slowed the ciliary beat did so in all three series. The elapsed time from the application of a drug to the reaction did not differ materially in the three series. In many instances a more rapid and more marked effect was obtained in the living rabbit than in the tissues used in the previous series. This would seem to indicate that the normal mucous sheet does not prevent the penetration of a drug incorporated in an aqueous or a Locke's solution.

TABLE 2.—*Results Obtained on Intact Turbinate with Drugs in Locke's Solution*.*

Drug	Effect																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cocaine, 5%	0	DR	0	0	0 3′	0 3′	0	0	DR 4′	0 3′										
Cocaine, 10%	DR 3′15″	DR 2′15″	DRa 1′12″	DR 4′35″	0	DR 3′35″	DR 2′	DR 2′	DR 1′30″	DR 2′										
Cocaine, 20%	SR 2′	SR 1′30″	DRa 35″	DR 1′30″	SR 45″	SR 30″	SR 30″	DR 2′	DR 1′	DR 1′										
Ephedrine, 3%	Ia	Ia	Ia	0	0	0 3′	0 3′	I	I	I	0 3′	Ia	0	0	I 45″	0 1′45″	Ia 1′30″	Ia 1′50″	Ia 1′20″	0 4′
Menthol, 1%	DR 2′30″	DR 4′	DR	0	DR 3′	DR 2′15″	DR 3′	DR 4′10″	DR 1′15″	DR 2′30″	DR	DR	DR	DR 3′30″	DR 3′10″	DR	DR 4′	DR	DR 3′45″	DR
Menthol, 0.5%	0	0	DR	DR 3′	DR 4′	DR	DR 2′30″	DR 3′	DR 4′	DR	DR 3′	DR 1′	DR	DR 2′	DR	DR 3′15″	DR 3′15″	DR 3′15″	DR 2′30″	DR
Thymol, 0.5%	S 1′	DR 2′	S 2′	S 1′	DR 1′15″	S 1′20″	S 1′10″	S 1′15″	S 2′	DR 1′30″	DR 30″	DR 49′	DR 1′30″	DR 30″	S 45′	S 1′	S 1′20″	DR 40″	DR 1′15″	DR 1′
Thymol, 1%	S 1′	S 2′	S 2′	DR 30″	S 1′	DR 50″	S 1′30″	DR 30″	DR 45′	S 45″	DR 45″	DR 1′	S 1′10″	DR 1′30″	DR 30″	DR 30″	DR 30″	DR 1′	DR 15″	DR 30″
Eucalyptol, 0.5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	I	0	0	0	0	0
Eucalyptol, 1%	DR 4′20″	DR 3′51″	S 2′	DR 3′	DR 3′	DR	DR 1′30″	DR 1′45″	DR 3′30″	DR 1′15″	DR 3′30″	DR 3′	DR 1′	DR 2′	S 4′5″	DR 4′	DR 2′	DR 1′	DR 1′20″	DR 2′5″

* Time five minutes, unless otherwise specified. I indicates increase; D, decrease; 0, no change; a, activity impaired before application of drug; S, stopped; R, recovery after washing with Locke's solution.

TABLE 3.—*Results Obtained on Intact Turbinate with Drugs in Aqueous Solution*.*

Drug	Effect																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cocaine, 5%	DR 3′30″	DR 4′	DR 1′	DR 2′	DR 1′15″	DR 4′15″	DR 2′40″	DR 1′50″	DR 1′5″	DR 2′3″										
Cocaine, 10%	DR	DR 3′	SR 3′	DR 3′	DR 1′15″	DR	DR 3′30″	DR 1′	DR	DR 2′40″										
Cocaine, 20%	DR 3′	DR	SR 0′	DR 1′	DR 3′	DR 1′40″	DR 1′50″	DR 1′	DR 3′	DR 4′	DR 1′	DR 2′								
Epinephrine, 1:1,000	S 45″	SR 0′	S 0′	S 1′	DR 20″	S 55″	DR 28″	SR 45″	SR 1′30″	S 30″	SR 0′	SR 0′	DR 5′	DR 0′	DR 0′	DR 5″	DR 0′	DR 5″	DR 10″	S 1′
Mercurochrome, 2%	DR 1′	DR 1′	S 1′	DR 1′	DR 1′	S 1′	S 1′	DR 2′	DR 30″	DR 20″	DR 20″	S 2′30″	DR 2′30″	S 2′	S 1′40″	DR 1′	S 2′	DR 1′30″	DR 2′7″	DR
Silver nitrate, 0.5%	S 1′	S 0′	S 1′15″	S 1′	S 0′	S 15″	S 0′	S 1′	S 30″	S 1′30″	S 0′	S 0′	S 15″	S 0′	S 0′	S 0′	S 0′	S 0′	S 0′	S 0′
Zinc sulphate, 2%	SR 30″	S 2″	SR 3′	SR 2′	SR 15″	DR 55″	SR 2″	DR 15″	DR 15″	DR 15″	DR 10″	DR 15″	DR 30″	DR 30″	DR 1′30″	DR 1′	DR 1′	S 1′	DR 38″	DR 30″
Mild silver protein, 5%	†DR	†SR	†DR 4′	DR 2′45″	†DR	†DR 4′	†DR 3′30″	†DR 2′	†DR 3′	†DR	†DR 3′20″	†DR	†DR	†SR 2′15″	†DR 2′	†DR	†DR 3′10″	†DR 4′	†DR	†DR
Mild silver protein, 10%	†DR	†DR 4′	†DR	†DR	†DR	†DR 3′30″	†DR 4′30″	†DR 2′	†DR 2′	†DR 3′30″	†DR 3′	†DR 2′	†DR 2′30″	†DR	†DR 2′	†DR 3′40″	†DR 3′	†DR 4′45″	I	†DR
Mild silver protein, 20%	†S	†DR 2′30″	†DR 4′	†DR	†DR 3′	†DR 2′45″	†DR 1′15″	†DR 2′30″	†S	†DR 3′15″	†DR 4′	†DR 1′30″	†DR 4′	†DR 3′10″	I	†DR 3′30″	†DR 4′30″	†DR 4′	†DR	I

* Time five minutes, unless otherwise specified. I indicates increase; D, decrease; 0, no change; S, stopped; R, recovery.

† Initial speeding.

TABLE 4.—*Results Obtained on Mucous Membrane of Rabbit's Antrum in Vivo**.

	1		2		3		4		5	
	EFFECT	RECOVERY	EFFECT	RECOVERY	EFFECT	RECOVERY	EFFECT	RECOVERY	EFFECT	RECOVERY
Cocaine, 5% In Locke's	None in 5′		None in 5′		None in 5′		None in 5′		None in 9′	
Cocaine, 10% In Locke's	D 1′	Norm. 2′ 20″	D 1′ 45″ S 2′ 40″	Fair 15′ 40″ Norm. 22′	S 15″	Fair 9′ Norm. 13′	S 15″	Fair 2′ 30″ Norm. 6′	S 45″	Fair 4′ Norm. 12′
Cocaine, 20% In Locke's	S 0″	Fair 24′ 30″ Norm. 61′	S 0″	Norm. 30′	None in 5′		S 15″	Norm. 27′	S 20″	Fair 7′ Norm. 10′
Ephedrine, 3% In Locke's	None in 5′		None in 5′		None in 7′		None in 8′		None in 12′	
Menthol Sat. Sol. In Locke's	D 3′ Very D 6′	Norm. 24′	D 6′	Norm. 19′	D 40″	Norm. 2′	D 1′ 30″	Norm. 3′	Not seen until 3′	Norm. 3′
Eucalyptol Sat. In Locke's	D 45″	Norm. 30′	S 0″	Norm. 5′	S 1′	Fair 7′ Norm. 29′	S 0″	Norm. 13′	S 0″	None in 5′
Epinephrine, 1:1,000	S 2′	Norm. 80′	D 0″ S 1′	Fair 78′ Norm. 84′	S 0″	Norm. 13′	S 0″	Fair 14′ Norm. 18′	S 0″	Fair 12′ Norm. 55′
Mercurochrome, 2%	D 1′	Norm. 2′ 30″	D 35″ S 1′ 15″	Fair 2′ Norm. 4′	D 8″ S 35″	Fair 1′ 45″ Norm. 2′ 15″	D 1′	Fair 2′ 30″ Norm. 3′ 30″		
Zinc Sulphate, 2%	S 5″	None in 3 hrs.	S 10″	None	S 5″	None	S 10″	None	S 15″	None
Mild Silver Protein, 10%	D 25″	Fair 1′ 30″ Norm. 2′ 40″	D 40″	Norm. 2′	D 20″	Norm. 2′	D 30″	Norm. 4′	D 20″	Norm. 5′
Phenyl Mercuric Nitrate, 1:10,000	S 1′	Norm. 3′ 45″	S 50″	Fair 2′ 15″ Norm. 5′	S 30″	Norm. 2′ 30″	S 10″	Norm. 1′ 30″	S 25″	Fair 2′ 20″ Norm. 4′ 30″

* *D* indicates decrease; *S*, stopped; *Norm.*, Normal.

Five per cent cocaine hydrochloride in Locke's solution produced no effect in any of the three series. Ten and twenty per cent cocaine hydrochloride in Locke's solution produced a more rapid and more marked effect in the living rabbit than in the freshly killed guinea pig.

Three per cent ephedrine sulphate in Locke's solution produced no slowing of the beat in any of the series. In the freshly killed guinea pig it produced a mild increase in speed in those cases where the activity was below par from the previous application of a drug. This was the only drug used under such conditions, and it was so used deliberately in some of the determinations to establish this particular effect. It seems to restore normal activity in certain instances where the speed has been depressed.

The saturated solution of menthol in Locke's (approximately 1 per cent) gave the same results in all three series; a mild slowing of the beat with complete recovery.

The saturated solution of eucalyptol in Locke's (approximately 1 per cent) gave somewhat variable results. In the excised tissue and the live rabbit it stopped the beat. In the former there was seldom any recovery. In the latter, recovery always took place. In the guinea pig the beat was seldom stopped but this may have been the result of very prompt washing. If washed before the beat ceased there was fairly good recovery. The effect appeared more quickly in the live rabbit than in the other two series.

Epinephrine hydrochloride, 1:1,000, gave the same immediate cessation of activity in both series in which it was used. Recovery in the freshly killed guinea pig depended on immediate washing with Locke's solution, and failed to occur in six of the twenty determinations. In the live rabbit recovery occurred in all of the five tests without washing.

Two per cent mercurochrome gave the same slowing with recovery in both series in which it was used.

Two per cent zinc sulphate produced a very rapid reaction in both series. If washed with Locke's solution before the beat was stopped or at the moment of cessation of movement, there was fair recovery in the guinea pig. In the living rabbit there was no washing and no recovery.

Ten per cent mild silver protein resulted in the same slowing of the ciliary beat with recovery in both series. The initial acceleration was not noted in the live rabbit, and the depressing effect appeared sooner than in the freshly killed guinea pig.

Phenyl mercuric nitrate, 1:10,000, produced rather prompt cessation of the beat, but recovery ensued in from one and a half to five minutes.

COMMENT.

The degree and prolongation of the effect in the living rabbit depended largely upon the location of the area under observation. When the drug merely touched the area and was carried away by gravity and the flow of mucus, the reaction was slight and the recovery prompt. In one instance there was no reaction at all to 20 per cent cocaine in the area which was visualized. If the cilia were near the floor of the sinus where the drug remained in contact, or was carried back over the cilia by the normal flow of mucus, the reaction was more marked and more prolonged.

In one of the observations two areas were visualized, one above the other. Eucalyptol was applied to the lower one and the cilia stopped immediately. The flow of mucus was maintained, however, by the cilia above, and at the end of a minute and a half had carried the drug up to the second area, and these cilia were also stopped. Twenty per cent cocaine, 2 per cent zinc sulphate and phenyl mercuric nitrate, 1:10,000, usually stopped the flow of mucus as well as the beat of the cilia.

Lucas and Douglas[12] have demonstrated by careful observation and numerous fixed and stained microscopic slides that the normal mucous sheet is composed of two layers. There is an overlying viscid sheet which is in contact with the tips of the cilia and a serous fluid layer in which the cilia vibrate. They make the following statements: "1. Slight drying, which does not affect the underlying cilia, could increase the viscosity of the mucous layer so that ciliary action would fail to move it. 2. Overabundance of fluid in the lower layer could elevate the mucus sheet so that the cilia would fail to make contact with it and thus be unable to propel it along. 3. Diminution of the fluid layer to the extent that the mucus settled close to the cellular surface would slow and probably stop the action of the cilia."

In the course of these experiments, the mucus sheet was observed to change character under certain conditions. Phenyl mercuric nitrate immediately produced a glazed, uneven appearance, as though the serous fluid layer had been drawn away, allowing the mucus to drop down on the cells themselves. Zinc sulphate and mercurochrome produced a similar effect, but in addition deposited a precipitate on the mucus itself. After the immediate reaction and recovery had

taken place with mercurochrome and mild silver protein, there seemed to be a continued precipitation on and into the mucus sheet, interfering with its movement and with the visualization of the cilia beneath it. There were also times when the addition of some fluid to the surface of the mucous membrane seemed to lift up the mucus layer. The reflex high-light became indistinct, the flow of the mucus decreased or stopped, and no evidence of the ciliary beat could be seen. All of these reactions had to be considered in interpreting the results of these experiments. When the mucous sheet was so altered that ciliary activity could not be seen, even if it were present, the observation was discarded.

Several times ephedrine and argyrol were applied to the mucous membrane on tampons, which were left in place five minutes each. This was done to see what effect the pack itself might have. When the pack was soft and gently applied the drugs produced the same effects which were noted when they were dropped on the membrane. The pack did alter the surface of the mucus slightly, however. When the pack was wound tightly and wedged against the membrane no ciliary activity could be visualized after its removal.

In comparing these results with those of other workers in this field, one must make allowances for the difference in methods. One investigator reports more marked response to 5 and 10 per cent cocaine in both the extirpated membrane and the living rabbit. He found a prolonged action with the 5 per cent solution and only occasional recovery with the 10 per cent solution. He noted the same immediate response to epinephrine 1:1,000, but saw no recovery. He obtained the same response with 2 per cent mercurochrome, but interpreted the 10 per cent argyrol as interfering mechanically with streaming and not affecting the ciliary beat. The difference in response to cocaine may be due to the fact that the drug was placed in Locke's solution for the tests reported in this paper. In the work with the freshly killed guinea pig the effects of cocain in Locke's solution and in aqueous solution were compared. Five per cent cocaine in water uniformly depressed ciliary activity but showed no such effect when used in Locke's solution. The ability of the cilia to recover after cocaine and epinephrine in this series may be due to the added protection afforded by the transparent window.

Injections of epinephrine, pilocarpine, atrophine, morphine and alcohol into the blood stream of the turtle were made by Lucas and Douglas.[8] They found these to have no effect on the activity of the tracheal cilia. Florey, Carleton and Wells[13] had previously reported acceleration of the flow of mucus in the trachea of the cat after

injection of pilocarpine. They did not comment on the speed of the ciliary beat. The result they noted was probably due to a change in the viscosity and supply of mucus.

Lucas and Douglas[8] reported the tracheal cilia to be normally continuously active in contrast to those in the frog's mouth, which were inactive until aroused by definite stimuli.[11] In the course of the present experiments, the cilia of the upper respiratory tracts of man, dog, rabbit and guinea pig were found to be normally continuously active. This coincides with the concept of the function of the cilia of the respiratory tract,[14] where their constant activity is required to keep the membranes clean.

CONCLUSIONS.

1. The use of transparent windows in the lateral walls of the maxillary sinuses of living rabbits permits the study of the cilia of the mucous membrane under conditions more nearly normal than heretofore has been possible. However, the method does not duplicate the natural conditions present in the unopened sinuses.

2. There are no essential differences, as far as could be determined, in the reaction of drugs of this series in freshly killed and in living animals.

3. The mucus sheet in the living animal does not constitute a barrier to the penetration of drugs incorporated in an aqueous or a Locke's solution.

4. Although many drugs depress or stop the activity of the cilia, only those in this series which are actual cauterizing agents produce any permanent injury. The effects of the others are only temporary when applied as drops, sprays or on tampons left in place but a short time.

5. When possible, it would be advisable to use the least toxic drug, or the most dilute solutions of a drug, to produce the desired effect. Menthol and eucalyptol, if used, should not be stronger than 0.5 per cent, and either one is preferable to thymol. Ephedrine would be better than epinephrine.

6. It is best to avoid as much as possible those drugs which clog up the mucus sheet with precipitate and interfere with its efficiency. This is especially true of mercurochrome, and to less extent of the higher concentrations of mild silver protein.

7. When nasal tampons are used they should be soft and should be inserted very gently.

8. Distilled and tap water cause slowing of ciliary beat. Therefore, it is suggested that drugs which are compatible be used in an isotonic solution, such as Locke's solution, rather than in ordinary aqueous solutions.

BIBLIOGRAPHY.

1. Lierle, D. M., and Moore, P. M.: Effects of Drugs on Ciliary Activity of Mucosa of Upper Respiratory Tract. Arch. of Otolaryng., 19:55 (Jan.), 1934.

2. Proetz, A. W.: Nasal Cilia in the Living Mammal. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 42:778 (Sept.), 1933.

3. Proetz, A. W.: Effects of Certain Drugs Upon Living Ciliated Epithelium. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 43:450 (June), 1934.

4. Sandison, J. C.: A New Method for the Study of Living Growing Tissues by the Introduction of a Transparent Chamber in the Rabbit's Ear. Anat. Rec., 28:281, No. 4, 1924.

5. Sandison, J. C.: Demonstration of Growing Tissues as Seen in a Transparent Chamber Introduced Into a Rabbit's Ear. Anat. Rec., 35:54, No. 1, 1927.

6. Sandison, J. C.: The Transparent Chamber of the Rabbit's Ear, Giving a Complete Description of Improved Technique of Construction and Introduction, and General Account of Growth and Behavior of Living Cells and Tissues as Seen with the Microscope. Amer. J. of Anat., 41:447, No. 3, 1928.

7. Proetz, A. W.: Effect of Temperature on Nasal Cilia. Arch. Otolaryng., 19:607, May, 1934.

8. Lucas, A. M., and Douglas, L. C.: Principles Underlying Ciliary Activity in the Respiratory Tract: III Independence of Tracheal Cilia in Vivo of Drug and Neurogenous Stimuli. Archiv. Otolaryng., 21:285, March, 1935.

9. Proetz, A. W.: Apparatus for Observing Ciliary Motion. Tr. Sect. Laryng., Otol. and Rhin., A. M. A., p. 260, 1933.

10. Proetz, A. W.: Nasal Ciliated Epithelium with Special Reference to Infection and Treatment. J. Laryng. and Otol., Vol. 49, No. 9 (Sept.), 1934.

11. Lucas, A. M.: Principles Underlying Ciliary Activity in the Respiratory Tract. I. Method for Direct Observation of Cilia in Situ and Its Application. Arch. Otolaryng., 18:516 (Oct.), 1933.

12. Lucas, A. M., and Douglas, L. C.: Principles Underlying Ciliary Activity in the Respiratory Tract. II. A Comparison of Nasal Clearance in Man, Monkey, and other Animals. Arch. Otolaryng., 20:518 (Oct.), 1934.

13. Florey, H., Carleton, H. M., and Wells, A. Q.: Mucus Secretion in Trachea. British J. of Exp. Path., 13:269 (June), 1932.

14. Yates, A. L.: Methods of Estimating Activity of Ciliary Epithelium Within the Sinuses. J. Laryng. and Otol., 39:554 (Oct.), 1924.

Hilding, Anderson: Ciliary Activity and Course of Secretion Currents of Nose, Proc. Staff. Meet., Mayo Clin., 6:285 (May), 1931; Influence of Ciliary Activity on Bacteriology of Nose: Direction of Ciliary Currents in Frontal Sinus of Dog, ibid., 6:320 (May), 1931; Physiology of Drainage of Nasal Mucus. Flow of Mucus Currents Through Drainage System of Nasal Mucosa and Its Relation to Ciliary Activity. Arch. Otolaryng., 15:92 (Jan.), 1932; Physiology of Drainage of Nasal Mucus: Cilia and Mucin in Mechanical Defense of Nasal Mucosa. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 41:52 (March), 1932.

Lucas, A. M.: The Nasal Cavity and Direction of Fluid by Ciliary Movement in Macacus Rhesus. Am. J. Anat., 50:141 (March), 1932.

LXVII.

THE RELATIONSHIP OF THE GUSTATORY TO THE OLFACTORY SYSTEMS.

LEON FELDERMAN, M. D.,

PHILADELPHIA.

The highly specialized senses of smell and taste are closely interrelated. Not infrequently, when one of the senses suffers impairment, it may correspondingly affect the other sense. The otolaryngologist, when referring to the sense of smell, usually has in mind as well the sense of taste, for the two are inseparably linked.

In the animal world the vertebrates and invertebrates are equipped with a sense of smell and taste to guide them safely in their peculiar environments. It may be well to consider a few fine points of the senses in animals before we enter into the higher zoologic scale of life.

While it is impossible to include, in this limited space, every form of insect life and its behavior, as far as these special senses are concerned, yet the insect that holds the greatest attention of the student of zoology is the ant, which readily lends itself for the purpose of experimentation and observation.

The ant, not unlike other insects, is divisible into a head, thorax and abdomen. The head of the ant is furnished by Nature with eyes, mouth and two pairs of antennæ. The typical ant has two large compound eyes, situated on either side of the head, and three simple eyes, symmetrically arranged in the front of the head. The antennæ project from the latter position, just above the level of the eyes.

Considerable discussion has been centered around the precise function of the antennæ. It is agreed by scientists that they are highly sensitive and have a distinct tactile function. Ants, when deprived of the antennæ, perish in their environments, for the antennæ serve not only as the organ of smell but also as the organ of hearing.

Sir John Lubbock[1] dipped a feather in essence of lavender and held it before the antennæ of an ant, with the result that the antennæ were immediately withdrawn, pointing clearly that their function is also that of smell.

From the mouth of the ant project two pairs of short-pointed organs, which correspond in function to the organ of taste in higher animals. This serves as a discriminating unit when accepting or rejecting food.

The nervous system of insects consists of a double thread which traverses the body and in turn connects with a series of ganglia, forming the brain work of the insect. Wroughton[2] refers to the peculiar Indian ant which travels single file and holds the alignment chiefly by the sense of smell, which shows that the power of communication resides in the antennæ.

Fabricius[3] disputed this observation, and from his own experiments found that ants march to a certain place and return by the same path by the use of their eyes, for they will overcome any obstacle placed in the path of their trail and will recover that same trail, although it entails considerable more time to do so.

Charles Bonnet[1] was one of the few who shared the thought that ants are directed in their migrations by special senses. As one biologist tersely states: "Nature has given to ants a language of communication by the contact of their antennæ; with these organs they are enabled to render mutual assistance in their labors and in their dangers, discover again their routes when they have lost them, and make each other acquainted with the necessities."

In the lower animals the sense of smell has been referred to as the "smell brain." In the lowest form of invertebrates, as the worm, mollusk or jelly fish, the sense of smell is an important part of their anatomic make-up, for without it they perish in their environments.

Sponges are known to possess musculature, and typify, in the zoologic scale, a close resemblance to a receptive mechanism among the invertebrates. The latter are often referred to as coelenterates, which have a form of nerve prolongations, connecting with the subjacent musculature, and in the presence of a stimulus will show vermiculate movements. One can observe the gullet opening and closing, proving conclusively that these invertebrates, such as sea animals, are capable of receiving sensations.

The olfactory organs in the aquatic animals differ anatomically from terrestrial animals. In fishes, the Amphioxus group, one can observe a single head end connected with the anterior end of the nerve tube which results in the olfactory organ. It is probable that this pit corresponds to the single median olfactory sac in the cyclo-

stome group. This single olfactory opening of the Amphioxus and cyclostomes is called Monorhine, and differs from other fish. Those in which the olfactory organs are obviously paired have been called Amphirhine. This applies to the aquatic animal, whereas in the terrestrial animal, as in man, we have external parts, such as nares, and the posterior part, the choanae.

In some mammals, such as the Orycteropus, one can find almost ten olfactory conchae. The greater number of conchae, the more keen scented the animal. Such we note in the (a) macrosmatic group. Those in which the number of olfactory conchae are fewer in number, such as in the seal, whale, monkey or man, the sense of smell is less acute and they are classed in the (b) microsmatic group. In other animals, such as the toothed whale, porpoises, etc., in which the olfactory organs have greatly degenerated and are devoid of olfaction, the species are known to belong to the (c) anosmatic species.

The vomero-nasal organ is present in all vertebrates except the fish. However, Gawrilenko[5] delineated this organ in sharks, and, by way of contrast, the Australian duck has this organ very well developed. The vomero-nasal organ can be studied to advantage in the dog and cat and has been described by Read as a tubular organ, somewhat kidney shaped. Although the nerves of the vomero-nasal organ have been traced to the olfactory region, yet Van Mihalcovics found that after burning out the nasal-palatine duct it did not interfere with the selection of food. The vomero-nasal organ is regarded as an accessory organ of olfaction, which helps to explain the filling up and emptying of the cavernous tissues. The vomero-nasal organ (Jacobson's organ) exists in a rudimentary state in man and is located at the muco-cutaneous junction of the floor of the septum. The vomero-nasal nerve is generally absent, and when present in man supplies it with general sensation from branches of the trigeminal and the sympathetic nerves.

The sense of smell in most animals attains a high degree of complexity and is a factor in determining the behavior of an animal in response to the change in its surroundings.

In the elasmobranch fish, the olfactory lobes form the greater part of the higher brain, and extirpation of these produces a loss of alertness and causes delayed reactions comparable to those which can be brought about in the higher types of animal by extirpation of the whole of the cerebral hemispheres.

Felderman,[6] in his volume, "Human Voice: Its Care and Development," states: "It is an auxiliary organ of smell to the lower animals whose self-preservation depends upon the efficiency of this important organ."

THE ORGAN OF SMELL.

This organ is situated at the upper part of the nasal cavities. Here the mucous membrane covering the superior and middle turbinate bones and the corresponding part of the septum is different from that covering the remainder of the nasal passages. In the lower parts of the nasal cavities the mucous membrane is of the ordinary respiratory type and is composed of ciliated columnar epithelium, containing a number of goblet cells. In the olfactory region the epithelium is much thicker, yellowish in color and apparently composed of a layer of columnar cells resting on several layers of nuclei. In human beings the olfactory organs are located in each nasal cavity. These cavities are separated by a nasal septum, which acts as a partition between the two nasal fossæ. As stated before, they have an external opening called the anterior naris, and an internal opening, the posterior naris or choanae. The lateral wall of these cavities are a series of folds, called nasal conchae. They are usually three in number: the inferior, the middle and the superior. Sometimes one may find a fourth concha called the supreme concha. According to Schaeffer, this concha may be observed in about 60 per cent of all human beings.

The olfactory nerve is composed of approximately twenty non-medullated filaments, which pass through the foramina of the lamina cribrosa, of the ethmoid bone into the anterior cerebral fossa, and after piercing the meninges, make up the olfactory bulb and become intracerebral. These fine filaments penetrate into the brain covering the olfactory bulb, which in turn synapse with the dendrites of the olfactory pathway. The final portion of the olfactory nerve becomes the terminal nerve. The latter has been demonstrated in the cadavers of infants and adults. The peripheral twigs can be found along the ethmoid bone where the nasal mucous membrane joins the olfactory regions.

The central organ of the "smell brain" (rhinencephalon) in point of evolution, phylogenetically, may be regarded as the oldest brain. Physiologists refer to it as *archi pallium*. The olfactory brain (rhinencephalon) is composed of two great divisions: (a) anterior, (b) posterior. Ferior found that electric stimuli in the region of the

gyrus uncinatus, followed by twitchings of the nose and lips, are disturbed by strong smells.

The olfactory cerebral cortex falls into two groups, namely: (a) olfactory cerebral cortex, (b) olfactory reflex centers. The olfactory bulb in man exists in a rudimentary state. It is elongated and oval shaped, yellowish in color, is situated in the lamina cribrosa of the ethmoid bone and gives origin to olfactory tract 18 to 20 mm. long. The olfactory bulb and tract lie close by in relation with the roof of the nasal cavity. The bulb rests upon the cranial surface of the lamina cribrosa of the ethmoid bone. Not infrequently it is encroached upon by the irregularity of the frontal sinus, such as the cell of crista galli or ethmoid cell. This anomaly may help to explain the anosmic condition. We have three kinds of olfactory epithelium, viz., (a) basal cells, (b) ordinary epithelium, (c) sustentacular cells or sense cells.

The olfactory receptors are, therefore, represented by a series of specialized end organs which receive impressions borne through air or water or both. These end organs are stimulated by aromatic and volatile substances which act upon the specialized olfactory mucous membrane of the nose. The peripheral organ of smell consists of an epithelium containing sensory cells which give origin to fibers forming the olfactory nerve. These cells are bipolar. Their central processes enter into the formation of the fila olfactoria, while their peripheral processes are equipped with a number of hair-like prolongations, at their extremities, called the olfactory hairs.

ODORS AND BEHAVIOR.

The specific rôle that odors play in the behavior of animals has been the subject of laboratory experimentation, because in animals olfactory sensitivity seems to have attained a higher degree of acuity than in human beings. In 1928 Liggett states that none of his experiments with rats had been designed to test olfactory ability, but rather various experimental results had been said to be influenced by olfaction.

In point, I wish to relate the following interesting experiments: Small[7] (1899), who tested the olfactory sensitivity of young rats during the first fifteen days of life by holding odors near the animal and observing the animal's behavior, found that the reactions could be divided into three kinds, on the basis of age of the animal: (a) In very early life there appeared to be an avoidance of all odors; (b) later there appeared an indifference to all but detrimental odors; (c) at the second or third week, there appeared positive reactions.

The specific problem that has occupied much attention concerns the rôle that olfaction plays in maze learning. Watson[8] (1907) found that the performance of animals, trained in a maze, was normal after the animals were made anemic. Vincent[9] (1913) refined the technic of the problem by coating the correct pathway in a maze with alternate strips of beef extract and cheese; his report was that the animals learned the maze faster but ran slower.

Air currents are necessary in conveying odorous particles to the olfactory membrane. Bidder's work, in 1844, indicates that olfaction was possible on inspiration and that expired air does not stimulate the organ of smell. Odors do not emanate from a given center and disperse in all directions as do sound and light. In 1917, Woodrow and Karpman[10] observed that the adaptation time for olfaction—that is, the time required for an olfactory sensation to wane completely, is in direct proportion to the vapor tension of the odorous material, and shows that olfactory stimulation depends upon the degree of activity of the gaseous particles. It has been recorded that odorous bodies, such as musk, could give off gaseous particles for a long period of time without showing an appreciable change of weight. The olfactometer substantiated these findings.

In testing olfactory acuity, the majority of workers have used the method of evaporating a known weight of substance in a given volume of air. Valentin[11] (1848) found that 1/2,000,000 of a milligram of oil of rose per cubic centimeter of this mixture was necessary for olfaction, and concluded that the total weight of oil of rose used in this operation was the very small amount of 1/20,000 of a milligram. The same observer found that water containing 1/2,000,000,000 of its weight of tincture of musk had a perceptible odor, whereas water containing only 1/3,300,000,000 of this tincture could not be distinguished from ordinary water. One gram of the odorous mixture called forth the characteristic smell and contained only 1/2,000,000 of a milligram of tincture of musk.

ADAPTABILITY OF OLFACTORY SENSATIONS IN INDIVIDUALS.

The analysis of olfactory sensations is rendered difficult by the fact that this sense in man plays but a small part in his struggle for existence. We have, thus, to deal with a sense which is in many respects vestigial. We see traces of extreme complexity in its possibilities of performance, but are baffled in our endeavors to reduce the whole of the phenomena to the simpler factors of which they are composed. Moreover, like all vestigial functions, the extent to which

the sense is developed varies in different individuals. Many, for instance, are unable to appreciate the smell of vanilla, or hydrocyanic acid, or of violets. On the other hand, in animals, such as the dog, the olfactory sense seems to play a major rôle in determining behavior, and the nervous associations which are the physiologic basis of ideas must in these animals be largely connected with olfactory impressions. Another factor which diminishes the acuity of olfactory sensations in man is that the sense organ becomes easily fatigued. It often happens that the inmates of a room are perfectly comfortable and may perceive no fault in the ventilation, although a newcomer from the outside at once remarks that the air is foul.

During the World War, when gas warfare was one of the main offensive weapons, the normal functioning of the olfactory system of the soldier acted as a safeguard. If by chance the sentinel on duty lacked the proper sense in detecting gaseous odors, then sometimes the lives of a battalion, yes, and even a regiment, would be endangered. When a soldier was stationed to do guard duty, one of his main purposes was during bombardment to perceive if the projectiles were laden with deadly fumes. Once he was satisfied that this precarious situation existed he was to cry out repeatedly "gas" and at the same time sound the klaxon horn. The soldiers so notified in a fraction of a minute would don their gas masks. It so happened during my experience that the enemy let down a gas barrage to initiate the oncoming of fresh troops. The gas signal was delayed with the result that 80 per cent casualties, which could have been prevented by a keen scented soldier, resulted in that particular regiment.

Adaptation and fatigue are closely interwoven. Individuals whose occupations expose them to disagreeable odors soon become insensitive and it has long been recognized that invalids are not affected by the mal-odors which may exude from their own bodies. Odors are known to be associated with memory. Certain agreeable or disagreeable odors may make a profound mental impression, and the particular event may be associated with a certain odor for many years.

To test the immediate effects of the continuous action of an odorous substance on the olfactory organ of man, Aronsohn[12] (1884) determined the length of time certain olfactory stimuli, at full strength, continued to call forth sensation. Thus, oil of lemon and oil of orange were smelled by nine persons, till the odors of these substances could no longer be perceived. The period necessary to bring about this obliteration of sensation varied from 2.5 minutes to

11 minutes, with an average of 3 minutes. An 0.2 per cent solution of cumarin in water was smelled for from 1.75 to 2.3 minutes, after which it was no longer sensed. Thus, olfactory exhaustion under strong stimulation is accomplished in a very few minutes.

Most of the experiments have been made with solutions which had no injurious effect upon the olfactory epithelium. According to Aronsohn, it is possible to excite sensations of smell if the nasal cavity be filled with normal saline fluid containing a very small portion of the odorous substance. The objections to this experiment is that it is almost impossible to fill the nasal cavities without leaving some air spaces, so that the olfactory sensations obtained might have been due to stimulation of the olfactory cells in such a space. There is, however, no *a priori* reason to deny the probability of Aronsohn's conclusions.

Certain individuals, whose olfactory sense is in other respects normal, have no power of distinguishing some odors. The olfactory sense is easily fatigued. If it be fatigued so that it be absolutely insensitive to one kind of smell, it is still normally excitable for other smells. This condition has been referred to by psychologists as "olfactory blindness." Proetz[14] states "That fatigue to one odor does not impair acuity to other odors."

It is possible by mixing odoriferous substances in certain proportions to annul their effect on the olfactory organ. Thus, four gm. of iodoform in 200 gm. of Peruvian balsam is almost odorless, and the same neutralization of odors is obtained if the odor of each substance be allowed to act separately on each side, by tubes inserted into each nostril.

Haller,[15] and particulary Linnaeus, have correlated odors that have formed the basis for many of our modern classifications, such as the one given by Zwaardemaker in 1895. In this, odors are arranged in nine general classes, each of which may contain two or more subdivisions. These nine classes are, briefly, as follows:[16]

1. Ethereal odors; three subdivisions: odors of fruits, beeswax, ethers.

2. Aromatic odors; five subdivisions: odors of camphor, cloves, lavender, lemon, bitter almond.

3. Balsamic odors; three subdivisions: Odors of flowers, violet, vanilla, cumarin.

4. Ambrosial odors; two subdivisions: odors of amber, musk.

5. Alliaceous odors; three subdivisions: odors of hydrogen sulphide, hydrogen arsenide, chlorine.

6. Empyreumatic odors; two subdivisions: odors of roast coffee, benzole.

7. Caprilic odors; two subdivisions: odors of cheese, rancid fat.

8. Repulsive odors; two subdivisions: odors of deadly nightshade, bedbug.

9. Nauseating odors; two subdivisions: Odors of carrion, feces.

More significant measurements were made by Fischer and Penzoldt[17] (1886) on chlorphenol and mercaptan. One milligram of chlorphenol was evaporated in a room of 230 cubic meters capacity and was thoroughly mixed with the air. This dilution called forth an unquestionable olfactory sensation. It contained 1/230,000,000 of a milligram of chlorphenol per cubic centimeter of air, or, if it is assumed that 50 cubic centimeters of air are the minimum needful for olfaction, the total amount of chlorphenol necessary was found to be 1/4,600,000 of a milligram. By a similar method it was shown that mercaptan, a liquid with a penetrating garlic odor, could be recognized at a concentration of 1/23,000,000,000 of a milligram for every 50 cubic centimeters of air. Notwithstanding this infinitesimally small amount of mercaptan, the quantity just designated was estimated by von Fray (1904) to contain some 200,000,000,000 molecules of mercaptan.

TABLE I.

Minimum concentrations for olfaction in thousandths of a milligram of substance per liter of air. (Passy (18), 1892.)

Substances	Thousandths of a milligram
Camphor	5.
Ether	1.
Citral	0.4 to 0.1
Heliotropin	0.1 to 0.05
Cumarin	0.05 to 0.01
Vanillin	0.005 to 0.0005

TABLE II.

Estimated potencies of alcohols, Passy (1892c).

Alcohol	Estimated Potency
Methyl	1
Ethyl	4
Propyl	100
Butyl	1000
Amyl	10000

TABLE III.

Pairs of neutralizing odors (Zwaardemaker (19), 1895, p. 168).

Pairs of odorous bodies	Neutralizing strength in olfacties
Cedarwood and rubber	2.75:14
Benzoin and rubber	3.5 :10
Paraffin and rubber	8.5 :14
Rubber and wax	14. :28
Rubber and balsam of Tolu	14. :70
Wax and balsam of Tolu	40. :90
Paraffin and wax	10. :20

TABLE IV.

Minimum concentrations for olfaction in millionths of a gram of alcohol per liter of air (Passy, 1892c).

Alcohol	Primary	Secondary	Tertiary
Methyl	1000		
Ethyl	250		
Propyl	10 to 5	40	
Normal Butyl	1		20 to 10
Isobutyl	1		
Normal Amyl			40 to 20
Active sinistral Amyl	0.6		
Inactive Isoamyl	0.1		
Caprylic			

TABLE V.

Concentrations in Milligrams of Chemical per liter of air.

Chemical	Intensity of Odor: Detectable	Faint	Noticeable	Strong	Very Strong
Ethyl ether	5.833	10.167	14.944	17.667	60.600
Chloroform	3.300	6.800	12.733	28.833	46.666
Ethyl acetate	0.686	1.224	2.219	4.457	6.733
Ethyl mercaptan	0.046	0.088	0.186	0.357	0.501
Pyridine	0.032	0.146	0.301	2.265	5.710
Oil of peppermint	0.024	0.032	0.109	0.332	0.348
Iodoform	0.018				
Methyl isothiocyanate	0.015	0.039	0.067	0.108	0.144
Butyric acid	0.009	0.021	0.066	0.329	0.580
Allyl isothiocyanate	0.008	0.012	0.024	0.030	0.201
Propyl mercaptan	0.006	0.020	0.028	0.043	0.054
Amyl thioether	0.001	0.007	0.011	0.012	0.015
Artificial musk	0.00004				

TASTE.

When we speak of the special sense of taste we refer to the muscular organ, namely, the tongue, which rests on the floor of the mouth cavity.

The dorsum of the tongue, the anterior two-thirds, curves in close apposition with the hard and soft palate, whereas the remaining posterior third forms the anterior wall of the pharynx.

The mucous membrane covering the dorsum of the tongue is studded with elevations, known as papillæ. The latter are covered with stratified squamous epithelium resting on a connective tissue base. These highly specialized epithelial structures are called taste buds, which serve as a receiving station for the varied gustatory stimuli. It has been stated by Tuckerman and Graberg[20] that the taste buds show development as early as the third month of intrauterine life.

Loven and Schwalbe[21] were among the early observers to describe the taste buds in the human being. One can observe in the avidity with which infants will grasp the maternal breast, which proves the importance of the rôle of the taste buds in life.

During the normal activity of the human being, the functional state of taste, not unlike smell, carries a constant stream of uninterrupted impulses from the cortical center to the peripheral part of the brain. Every minute of the day brings about modifications of these senses and registers the simplest environmental alterations to the most profound and perplexing.

The end organs are ellipsoidal, conical or oval bodies, measuring 0.70 to 0.80 mm. in length, and which are embedded in the stratified epithelium scattered over the tongue. A few are also found on the hard palate, the anterior pillars of the fauces, the tonsils, the posterior portion of the pharynx, epiglottis, the larynx and the inner surface of the cheek. On the tongue they are chiefly found in the grooves around the circumvallate papillæ of man, and in the grooves of the papillæ filiatæ of rabbits. A few are also present on many of the fungiform papillæ. They consist of medullary and cortical parts, the former being composed of columnar or sustentacular cells, the latter of thin fusiform cells, the taste cells proper.

The taste buds consist of highly specialized neuro-epithelium with so-called supporting cells. They are lanceolate, wedge shaped or columnar and possess large vesicular nuclei.

The basal cells, which are rarely more than a dozen in number, are also called the sustentacular cells. The gustatory cells are situated

slightly deeper than the supporting cells and their function is to receive the stimuli.

The nerve distribution of the taste buds arise from branches of

1. Trigeminal
2. Glossopharyngeal
3. Chorda-tympani nerve branch of facial (VII)
4. Lingual

The central connections of the trigeminus send out axones as arcuate fibers which pass to the facial and glossopharyngeal motor nuclei. The lingual nerve, a branch of the trigeminal, sends filaments to the tongue to supply the mucous membrane of the anterior two-thirds dorsum of the tongue; its fibers have their main termination in the filiform and fungiform papillæ. The lingual nerve communicates with the chorda-tympani nerve, a branch of the facial. The chorda-tympani nerve is a branch of the facial which supplies the mucous membrane, especially the anterior two-thirds of the dorsum of the tongue, whose function is the transmitting of taste impulses. The sensory nuclei of the glossopharyngeal nerve rises as a tapering column of gray matter and is called the spinal nucleus and becomes associated with fasciicules solitarius, which begins in the upper border of the medulla and sends fibers to the trigeminal, glossopharyngeal and vagus.

The central connections of the sensory part of the glossopharyngeal nerve through the dorsal sensory nuclei are concerned in receiving the taste impressions. When we consider that various fibers of the trigeminal nerve compose the pars intermedia of Wrisberg and are distributed peripherally by the chorda-tympani nerve which also carries taste impulses. That is, patients with perforated drum who instill medication through the medium of the ear dropper report to the physician tasting of the medicine. By some anatomists this is described as an aberrant nerve of the glossopharyngeal.

The lingual branches are the terminal filaments of the glossopharyngeal nerve. The posterior branch sends a number of filaments that supply the circumvallate papillæ which furnishes sensation to the mucous membrane of the posterior part of the dorsum of the tongue, the glosso-pharyngo-epiglottic folds and the lingual surface of the epiglottis. The anterior branch supplies the lateral part of the tongue half way to the tip.

The taste buds have been divided into five types, viz.: (a) conical, (b) filiform, (c) fungiform, (d) foliate, (e) vallate. The taste

buds are situated from the tip to the back of the tongue in the order named. In these regions taste buds may vary from six to a couple of dozen. Taste buds, to function well, must have a moist surface, be well lubricated, and for this reason the salivary glands of the mouth secrete saliva to keep the taste buds in a moist state for adequate and proper reception. Every papilla carries a number of taste buds, which are open to stimulation by two or more sapid solutions. The peripheral end of the fusiform cell projects through the orifice of the taste bud and acts as a receiving station for the fluids contained in the mouth cavity.

The end organs of the sense of taste compose this group. They are aroused by chemical stimulation and consist of taste buds on the tongue and pharynx and part of the epiglottis. These organs are responsive to sweet, sour, salty and bitter substances. The end organ is a collection of specialized epithelial cells supporting the specific sensory ending. At the apex of the papilla is situated the taste pore through which the fluid reaches the sensory cells.

We distinguish four definite primary taste sensations, viz.: sweet, sour, bitter and salt. Some writers add to these an alkaline taste and a metalic taste. Many substances owe their distinctive character, when taken into the mouth, to the fact that they stimulate not only the taste nerves but have a specific action for the nerve endings. Thus acids when in weak solution have an astringent character beside their sour taste, and, if strong, produce a burning sensation. The primitive taste sensations cancel the effects on one another if excited simultaneously. A dilute solution of sugar is rendered almost tasteless by the addition to it of a few grains of common salt. If the primitive taste sensation are more strongly excited, we get a mixed sensation in which the components can still be distinguished. Thus, one eating ice cream and followed by grapes: the taste of the ice cream is replaced by the sourness of the grapes. Adding sugar to lemon juice not only diminishes its acidity, but produces a mixed taste sensation, the quality of which is pleasant and in which the components, sour and sweet, can be easily distinguished. We get no such fusion of sensations in the eye, where a sensation of white light may result from stimulation of the retina by two complementary colors. Stimulation of one kind of taste organ heightens the sensibility of the other taste organs.

Olmstead[22] did some experimental work on catfish amiurus. He cut the gustatory nerve which resulted in degeneration. He further observed that these taste buds underwent destruction by phagocytes and the taste cell did not return until the nerve was regenerated. It is,

therefore, safe to conclude that the activity of the taste bud depends on the activity of the nerve cells. Krause,[23] in experimenting, noted the effect on taste when he extirpated the ganglion of the trigeminal nerve and found that in some instances taste was entirely obliterated from the tongue, but in other cases it was only reduced. Cushing held that taste had nothing to do with the trigeminal nerve but the glossopharyngeal played a decided rôle.

PRIMARY TASTE SENSATIONS.

Sweet:

Sweet taste can be sensed at the tip of the tongue, and it gradually diminishes along the lateral margins to the base. It is excited by the diatomic and polyatomic alcohols of the aliphatic series, by the aldehydes and ketones derived from these alcohols, and especially by the hexoses, whose polymerization products, the disaccharides and polysaccharides, are in this respect particulary important. Besides these carbohydrates, other organic compounds such as chloroform, dextro, asparagine and saccharine, have sweet tastes. Among inorganic substances, neutral acetate of lead, often called sugar of lead, and the salts of gluomium are known to be sweet. Solutions of the alkali, in appropriate dilutions, are known to excite this primary taste.

All of the amino-acids have a sweet taste. The sweet taste, like the bitter taste, is associated with organic compounds. It centers about the alcohols and particularly the sugars in much the same way that the bitter taste does about the alkaloids.

Sour:

The sour taste is best developed on the lateral edges of the tongue and diminishes toward the tip, the base and the central anesthetic area.

If an electric current is passed through the human body in such a way that the anode is applied to the tongue and the cathode to some other part, a sour taste develops around the anode. If the electrodes are reversed in position, an alkaline taste develops around the cathode. This conforms with what takes place when an electric current is passed through an alkaline solution such as saliva. Hydrogen ions appear at the anode, and hydroxyl ions at the cathode. If electricity is passed completely to the top of the tongue there is a burning, bitter sensation which changes to a sour metallic taste. Kahlenberg thought the hydrogen ion had a great deal to do with the presence of the sour taste. A 0.0035 molar solution of hydrochloric acid produces a similar taste.

Salt:

The saline taste is exemplified by common salt. One must understand that the salty taste of sodium chloride is due to chlorine ions and not to sodium ions. Potassium chloride and lithium chloride are salty in taste.

Bitter:

The bitter taste is more characteristic of the base, especially the vallate papillæ. The alkaloids act as a stimuli, such as cations as magnesium, ammonium and calcium, and possibly the anion of picric acid. Bitter can be induced by the alkaloids such as morphine, cocaine, pilocarpine, quinine, nicotine, strychnine. These substances can be tasted in great dilutions, e. g.: (a) Quinine hydrochloride can be tasted in a solution as dilute as 0.00004 molar. (b) Strychnine monochloride can be tasted in 0.00006 gram per liter of water. (c) Quinine hydrochloric can be tasted in 0.00004 molar solution in addition to the four primary tastes. In many instances, when dissolved in the mouth, it not only stimulates the taste but also the nerve endings. When dilute hydrochloric acid is taken into the mouth it has a tendency to pucker up the mouth, giving an astringent like action, which the patient describes as a sour taste, lasting for many minutes, depending entirely upon the activity of the taste buds. Giving the patient a few grains of common salt, after having had a sugary solution in his mouth, will, in the course of a few minutes, cause the taste of the sweet solution to entirely disappear. This is especially true when one takes a bitter alkaloid, such as quinine. A sweet substance taken immediately afterward has no appreciable effect. In mixing paint we know that a certain fusion of colors exists. So, too, with taste. A fusion of taste has been alluded to when we make lemonade. When we add sugar, we get a taste of the lemon and of the sugar. Very often the sweet taste predominates over the lemon or vice versa, depending a great deal upon the proportional mixture of the ingredients of the drink. Patients have often reported that after eating salty herring, distilled water will have a somewhat sweetish taste.

The tongue is not uniformly sensitive at all points to all tastes. The posterior part of the tongue is more sensitive to bitter tastes; the tip and sides can be excited more readily by sweet and sour substances. A difference may even be detected between the circumvallate papillæ themselves. A mixture of quinine and sugar applied to one of the papilla may excite chiefly a bitter taste, while with an adjacent papilla a sweet taste may predominate.

By certain drugs we can depress the sensibility of the taste organs and then we find that the various tastes are affected in varying degrees. Thus, on painting the tongue with cocaine, the first effect is a diminution of tactile and pain sensibility, so that the application of acid evokes a very sour taste without any of the astringent or stinging sensations normally aroused by the contact with the acid. Otolaryngologists who use strong solutions of cocaine in the nose and throat have patients report to them that their sense of taste and smell is obliterated, if only temporarily, and when the sense of taste and smell returns they become more acute. Stovaine is also known to abolish sweet and bitter without obliterating saline and sour. Complete loss of taste is called ageusia. This is experienced usually by hysterical people and by those in an abnormally nervous state. Attempts to measure the interval of time between the application of a stimulus to a gustatory portion of the tongue, through the medium of an electric current, was 0.167 seconds. The length of time it takes for the sensation to be registered depends entirely upon the chemical, as well as the particular portion of the tongue stimulated, since there is a very marked variation of the structure of the taste buds from the base to the tip of the tongue.

The olfactory and gustatory nerves are an interesting study, not only for the specialist, but for the general practitioner as well. Early manifestations of intracranial and extracranial disturbances can be traced when taking a careful history of the functions of the senses of taste and smell.

A gradual impairment of taste and smell may be an early clue to central or peripheral lesions of the brain, and when one considers the complex ramifications of these special senses with the cranial nerves, cervical sympathetic and parasympathetic systems, one can appreciate the importance of the physiologic behavior of the gustatory and olfactory systems.

1327 SPRUCE STREET.

BIBLIOGRAPHY.

1. Lubbock, Sir John: Ants, Bees, Wasps. E. P. Dutton, New York.

2. Wroughton, R. C. (1892): Our Ants. J. Bomb. Nat. Hist. Soc., Part I: 48 pp., 2 pls.; Part II: 29 pp., 2 pls.

3. Fabricius, J. Chr. (1775): Systema Entomologiæ, pp. 391-306. (1776) Genera Insectorum, p. 130. (1781) Species Insectorum 1:488-494. (1787) Mantissa Insectorum 1:307-311. (1793) Entomologia Systematica Emendata et Aucta, 2:349-365. (1798) Entomologiæ Systematicæ Supplementum, pp. 279-281. (1804) Systema Piezatorum secondum Ordines, Genera et Species, pp. 395-428.

4. Bonnet, Charles (1779-83): Observations sur de petites Fourmis qui s'etaient établies dans la tête d'un chardon à bonnetier. Oeuvres d'Histoire Naturelle et de Philosophie. Neuchatel, 1:523.

5. Gawrilenko, A. (1910): Die Entwickelung des Geruchsorgen bei Salmo salar. Anat. Anz. Bd., 36, pp. 411-427.

6. Felderman, Leon: Human Voice: Its Care and Development, 1931. Henry Holt & Co., New York City, p. 65.

7. Small, W. S.: Notes on the Psychic Development of the Young White Rat, Behavior Monographs, Ser. No. 5.

8. Watson, John B.: Behavior, An Introduction to Comparative Psychology. Henry Holt & Co., New York, pp. 399-423, 1929.

9. Vincent, Stella B.: The Function of the Vibrissæ in the Behavior of the White Rat. Behavior Monographs, Ser. No. 5.

10. Woodrow, H., and Karpman, B. (1917): A New Olfactometric Technic and Some Results. J. Exp. Psychol., Vol. 2, pp. 431-447.

11. Valentin, G. (1848): Lehrbuch der Physiologie des Menchen. Bd. 2, Abt. 2, p. 831.

12. Aronsohn, E. (1884): A Beitrage zur Physiologie des Geruchs. Arch. Anat. Physiol., physiol. Abt. 1884, pp. 163-167.

13. Aronsohn, E. (1886): Experimentelle Untersuchungen zur Physiologie des Geruchs., pp. 320-357.

14. Proetz, Arthur W.: "Fractional Fatigue" of the Olfactory Apparatus. Arch. of Otolaryng., 1:638-641 (June), 1925.

15. Haller, B. (1909): Die phyletische Entfaltung der Sinnesorgane der Saugetiersunge. Bd. 74, pp. 368-466.

16. After Henning: Ztsch. f. Psychol., 73, 240-57.

17. Fischer, E., and Penzoldt, F. (1886): Über die Empfindlichkeit des Geruch sinnes. Sitsb. phys-med., Bd. 18, pp. 7-16.

18. Passy, J.: Les proprietes odorantes des alcools de la serie grasse. Cmpt. rend. Acad. Sci., Paris, tome 114, pp. 1140-1143.

19. Zwaardemaker, H.: Book I, J. Physiol., 45-53: pp. 54-73.

20. Tuckerman, F.: Development of Taste Organs in Man. J. Anat. Physiol., Vols. 23 and 24.

21. Loven, C.: Arch. mik. Anat. Bd. 4, pp. 63-110.

Schwalbe, G.: Arch. mik. Anat. Bd. 3 and 4, p. 504, 1867.

22. Olmsted, J.: J. Comp. Neurol., Vol. 31, 465-468.

23. Krause, W. (1876): Allgemeine und microscopische Anatomie. Hanover, p. 581.

LXVIII.

TORULA MYCOSIS IN MAN WITH SPECIAL REFERENCE TO INVOLVEMENT OF THE UPPER RESPIRATORY TRACT, WITH CASE REPORTS.*

WILLIAM D. GILL, M. D.,

SAN ANTONIO, TEXAS.

The history of pathogenic yeasts is comparatively recent. In 1890 Miller,[1] in a monograph entitled "Bacteria of the Human Mouth," stated that there was not a single lesion of the mouth which was due to yeast organisms. Investigators since then have found that such was not the case, as evidenced by numerous reports in medical literature touching upon the pathogenic yeasts and the lesions produced by them. The first observation on yeast infection in mankind originated in 1894 when Busse,[2 3] discovered a yeast-like organism in a leg tumor which had been diagnosed as sarcoma. The disease proved fatal and at autopsy similar organisms were isolated from other foci in the viscera which caused this investigator to believe that he had found the etiologic factor in sarcoma. The organisms isolated proved to be nonpathogenic for animals. Investigating further, he found yeast-like organisms in another human malignant tumor, and Nichols,[4] in studying the characteristics of these organisms, found them to possess a certain degree of pathogenicity for animals.

In 1896 Gilchrist[5] described a yeast-like organism, the cryptococcus dermatitidis, as the etiologic factor in certain ulcerative cutaneous lesions known as blastomycotic dermatitis, or cutaneous blastomycosis.

In 1902 Frothingham[6] described a tumor mass in the lung of a horse which he attributed to the action of a yeast-like organism. He designated the disease as torulosis and the organism responsible for it as torula.

Yeast-like organisms are often encountered in routine bacteriologic examinations of the mouth and pharynx, but are usually considered as saphrophytes of little or no importance.[7] However, there

*Presented as candidate's thesis to the American Laryngological, Rhinological and Otological Society, 1935.

are certain yeasts which have definite pathogenic properties and attack the mucous membrane of the respiratory tract, causing lesions which may assume grave proportions.

There is much confusion in medical literature so far as classification of infections due to yeast-like organisms is concerned. Broadly speaking, the term blastomycosis includes a variety of affections due to yeast-like organisms, but there are several subdivisions of the genus blastomycetes. Pathogenic yeasts or blastomycetes have been divided into four general groups: the torulæ, monilia, oidiomycetes and the coccidioides. All have been grouped under the general heading of blastomycetes and as belonging to the fungi imperfecti. Reference to Table No. 1 will show the comparative cultural and morphologic characteristics of the pathologic yeasts named above.

Torulæ differ from the true yeasts or saccharomyces in the absence of endospores and in their more marked pathogenicity for animals. Their ability to ferment the sugar bearing media differs from that of the true yeasts and is one of the factors governing their classification. They are aerobic organisms and in recent cultures are gram positive, in older cultures gram amphophile. Torula is an oval or round, double contoured, highly refractile organism. In tissue it buds but does not sporulate. In cultures it buds but never produces mycelia. Budding usually occurs in the medium sized and large forms. All stages of reproduction may be seen from a small bud-like projection on the circumference of the organism to the dumbbell forms where the mother and daughter cells are of equal size. The two bodies usually separate when this latter stage is reached, though occasionally they remain connected by a narrow, faintly staining band. The daughter cell usually breaks off when it reaches one-half or two-thirds the size of the mother cell.

Torulæ are widely distributed in nature and have been cultivated from wasp nests, the stems of many grasses and plants, and bodies of many insects.[8] They have been found in canned butter[9] and in milk.[10] They are ordinarily considered nonpathogenic, becoming pathogenic only under certain conditions.

The vitality of yeasts is prodigious, and once they become parasitic upon mankind they are overcome with the greatest difficulty, if at all.

Stoddard and Cutler, in 1916,[11] made the first real attempt to definitely correlate the clinical and pathologic features of the disease known as torulosis with the morphologic and cultural characteristics of the organism producing it, and published the result of their inves-

TABLE No. 1.

DIFFERENTIAL FEATURES OF YEAST, TORULA, OIDIOMYCOSIS AND COCCIDIOIDAL GRANULOMA.

(Modified from Stoddard and Cutler, Shapiro and Neal)

	Genus	Reproduction	Sporulation	Mycelium	Sugars	Pathogenicity	Lesions	Pathologic Characteristics	Size of Organism in Microns
FUNGI IMPERFECTI — BLASTOMYCETES	Saccaromycetes	Buds	Ascospores	Absent	Fermented	Feeble	Skin	Necrosis: epithelial overgrowth: giant cells abscess formation Polymorphonucleosis	
	Torula	Buds	Absent	Absent	Usually not fermented	Moderate	Nervous system: other organs to less extent: Respiratory tract, skin rarely	Chronic inflammation: caseation occasional: polymorphonucleosis slight or none unless secondary invaders present: gelatinous matrix	1-13
	Monilia	Buds	Absent	(±Variable)	Fermented	Moderate	Mucous membrane mouth and gastrointestinal tract: slight skin pigmentation	Chronic ulceration	5-10
	Oidia	Buds	Absent	Present	Not fermented	Slight	Skin always: often bones, internal organs and brain	Necrosis: epithelial overgrowth: miliary abscesses: tubercle-like nodules: Polymorphonucleosis: No gelatinous matrix	3-30
	Coccidioides	Never buds	Endospores present	Present with aerial hyphae	Not fermented	Marked	All organs: often skin	Nodules and cysts: giant cells: caseation: abscess formation: polymorphonucleosis: no gelatinous matrix	5-85

tigation in an excellent monograph. The subject of torulosis was reviewed by Sheppe[12] in 1924, Shapiro and Neal[13] in 1925, and Stone and Sturdivant[14] in 1929.

There seems to be no particular geographic focus where torulosis is endemic, though some writers are inclined[15] to regard torulosis as more or less indigenous to the San Joaquin Valley in California. A survey of the literature on the subject reveals that in the United States cases have occurred in New York, Massachusetts, Florida, Arizona, Illinois, Texas, District of Columbia, West Virginia, Virginia, California, Ohio and Pennsylvania. In foreign literature cases have been reported from Germany, Australia and Japan.[8]

Stone and Sturdivant[14] state that of the usual experimental laboratory animals, mice and rats are quite susceptible to torula infection while guinea pigs, rabbits and dogs are only slightly so.

The chief manifestation of torula infection noted by most writers on the subject has been a meningo-encephalitis which usually runs a subacute or chronic course and invariably terminates fatally. Most instances of torula infection reported have been of this nature and the majority of investigators indicate that the organisms may have gained entrance through the nose, throat or lungs. Diagnosis in most of the reported cases has been made by finding yeast-like organisms in the spinal fluid and by subsequent study of their cultural characteristics determining that they were torulæ. In some instances the disease was undiagnosed until the lesions in the central nervous system were examined histologically after the death of the patient. The clinical symptoms in this type of meningitis do not differ materially from other types except for the tendency toward chronicity. The duration of the meningo-encephalitic process is somewhat variable, the shortest recorded duration being three weeks, while the longest was two years. The average duration of the reported cases has been somewhat less than five months.[16 17 18] Their pathologic effect in nervous tissue in all probability is produced in two ways, according to Rappaport and Kaplan,[19] first by the mechanical pressure which accompanies their growth, and secondly by the action of the enzymes which they elaborate.

Repeated examination of the spinal fluid may be necessary to discover the organisms, as often times the torulæ are missed at first, only to be detected on subsequent examinations. They may be mistaken for lymphocytes, and in spinal fluid examinations where an excessive number of lymphocytes is reported the fluid should be rechecked for the presence of yeasts. Practically, therefore, we should

not be content with findings of a single spinal fluid examination where torulosis of the nervous system is suspected.

Often times the growth of torulæ on artificial media is slow, and for this reason cultures should be observed at least two weeks before being discarded.

Even the fermentation reactions of torulæ are subject to some variation which is responsible in a measure for the conflicting statements encountered in medical literature concerning their ability to ferment the various sugars. It has been observed by certan writers that the organisms frequently fail to ferment culture media containing low concentrations of the sugars, but when higher concentrations are used, 2.5 per cent, for instance, definite gas production takes place. This is of practical importance in that culture media used in the search for this organism should comprise media in which the higher concentrations of sugars is employed in addition to the usual weaker sugar bearing media ordinarily used.[20]

Most strains of torulæ appear to have a special predilection for the central nervous system, although there are some strains that evidently do not. The postmortem lesions found in the brain consist of foci of round cells associated with giant cells in which are found the budding yeast-like organisms. A marked resemblance of these lesions to those of tuberculosis is noted by practically all writers. A solution or lysis of tissue is present in these foci which is responsible for the name used to designate at least one species of pathogenic yeast, namely, torula histolytica. Many cases of torula infection of the central nervous system in the past have no doubt escaped detection by simulating tuberculosis, meningitis or brain tumor.

Many writers are of the opinion that the atrium of infection in torula meningitis is the respiratory tract. According to Berghausen,[21] slight traumatism to the oral or pharyngeal mucous membrane predisposes to torula infection by creating an area of lowered resistance upon which pathogenic yeasts may become engrafted and assume a parasitic rôle.

Lloyd Jones,[22 23] in an analysis of twenty-two cases of torulosis collected from medical literature in 1927, noted that eleven had ear, nose or throat involvement at some stage of their illness. In addition he reported the case of a patient afflicted with a destructive ulcerative lesion of the soft palate and nasopharynx which was due to torula. Berghausen,[21] in 1928, reported an instance of a torula lesion involving the dorsum of the tongue, and Alvarez,[24] in 1929, reported a

filamentous lesion involving the dorsum of the tongue from which a red torula was isolated. Turck[25] reported an instance of torulosis of the central nervous system in which the patient had an associated pharyngeal abscess due to torula.

There are in addition many interesting reports of pathogenic yeasts invading the air passages, which have been published under the title of blastomycosis. A variety of localities have been involved, the larynx, tongue, pharynx, frontal sinus, etc., but notwithstanding the fact that these reports are most interesting they have not been discussed in this article due to the fact that exact classification of the responsible yeast has not been possible under the title of blastomycosis.[26 27 28 29 30 31]

Freeman[32] and others call attention to the frequency with which torula lesions of the central nervous system occur about the optic chiasm and about the Sylvian fissure, a point which they feel has given strength to the belief that the source of the infection, so far as the central nervous system is concerned, is the upper respiratory tract.

Freeman[32] calls attention to the fact that there are three distinct types of lesions encountered in the central nervous system, the meningeal, perivascular and embolic forms, each with its own characteristic histologic picture. In the early lesions of torulosis, especially in the central nervous system, lymphocytic infiltration in conjunction with giant and endothelial cells associated with areas of tissue solution or lysis, dominates the picture microscopically, while in older lesions hyalinization is present.

Generalized invasion leads to meningeal and cerebral involvement, and not infrequently localization in other viscera as well. There is a striking similarity between torulosis and miliary tuberculosis and most writers on the subject of torulosis call attention to the fact that many cases are missed due to this striking resemblance, which extends even to the microscopic picture, and is so pronounced that unless the examiner is on the alert the microscopic diagnosis may be missed and the disease considered as tuberculosis.

Torula invasion of the lungs has been noted by Hirsh and Coleman,[33] Sheppe[13], and also Healy and Morrison.[34] Pulmonary tuberculosis is not infrequently a concomitant disease, which adds to the diagnostic difficulties.[35 36] Craik[37] believes that yeast infection of the bronchopulmonary tree predisposes to tuberculosis. Tonsillitis and otitis media have been reported as preceding the pulmonary invasion with torula. Brewer and Wood[3] report an instance of involvement

of the lumbar muscles and vertebral column with torulæ. Weidman,[39] McGehee and Michelson,[40] Verse,[41] Urbach and Zach[42] and Rappaport and Kaplan[11] report skin lesions due to torula.

Alvarez[21] has called attention to the fact that pathogenic yeasts may become sufficiently invasive to produce antibodies in the patient's blood, a fact which points to establishment of a certain degree of immunity. According to Berghausen,[21] intracutaneous administration of an extract of the torula reveals sensitiveness to them.

On mucous membranes such as those of the hard or soft palate or in the tonsillar region, the lesions are sufficiently characteristic in appearance to merit a strongly presumptive diagnosis of torula infection from their gross appearance.

Briefly, these lesions begin as an area of slight induration, which is only mildly inflammatory in character and in most instances soon shows paracentral softening and subsequently ulceration. In ten days to two weeks a central necrotic plug is formed which is more or less firmly attached at its base. The ulceration may invade the underlying tissues and, where bone is present, it is often exposed but not invaded. The central necrotic mass is usually cast off spontaneously within a week or ten days, leaving an excavated granular area which in color shows little deviation from normal. There is a surprisingly small amount of surface exudation, the scanty material present being thin yellowish white exudate which is easily wiped away. The exudate on microscopic examination is found to be loaded with numerous budding forms. Culture of this material as well as histologic examination of curettings or of a biopsy specimen reveals the presence of the budding forms in the tissue. In order that the causative organisms may be definitely classified it is necessary that their cultural reactions in the common sugar media be observed. Subjectively the lesions are intensely painful, and when the pharyngeal or tonsillar tissues are involved dysphagia is the chief complaint of the patient. There may be, and usually is, an accompanying rise of temperature. Usually there is only slight elevation of the leucocyte count, though exceptions to this rule occur, especially when secondary pyogenic infection is present.

Healing of the mucous membrane lesions is influenced largely by the type of therapy applied and occurs by granulation tissue filling in the defect.

The local lesions of torulosis must be differentiated from the lesions of tuberculosis, syphilis, carcinoma, Vincent's infection, as

well as mycotic lesions of the mucous membrane, such as anthrax, streptothricosis, cladothricosis and moniliasis. Cytologic examination of a smear taken directly from the lesion may reveal the presence of budding forms, but the diagnosis of torulosis is confirmed in the laboratory by cultural studies. Curettement may reveal the budding forms where a surface smear has failed. Biopsy with a punch forcep is an excellent means of obtaining tissue for histologic examination, but should be resorted to only when other methods of diagnosis have failed due to the greater danger of extension of the infection by breaking down protective barriers when this method is used. Curettement is a somewhat less dangerous procedure, and is recommended as preferable to punch biopsy. Cultures may reveal the causative organism when direct smears have failed to do so, and it may be reiterated that they are always necessary for exact classification of the organism. The differential diagnostic advantage of the Wassermann reaction and alexin test should not be overlooked.

Berghausen[21] states that cutaneous hypersensitiveness to torulæ exists in patients with torulosis and may be elicited by the intracutaneous administration of an extract of torula organisms.

Rappaport and Kaplan[11] call attention to the diagnostic advantage of immunologic reaction in laboratory animals, such as the agglutination, absorption and complement fixation reactions in torula infection.

So far as diagnosis of visceral lesions is concerned, pulmonary involvement may be suspected when torulæ are constantly present in the sputum, but cultural reactions must be resorted to for definite classification of the yeast-like organisms. There is no definite diagnostic physical or roentgenologic sign of pulmonary torulosis. The same may be said of bone involvement and involvement of other viscera such as the liver, spleen, kidneys, etc. Infection of the urinary bladder with torulæ has been discovered antemortem through examination of the urine.[18] Histologic examination of tissue obtained at necropsy may provide the first evidence of the true nature of the disease from which the patient died.

Rappaport and Kaplan[11] have repeatedly isolated torulæ from the blood stream in a patient with torula meningitis, before death. Torulæ were found in the blood stream in one of our patients, but it was found only once. This patient recovered under intensive therapy which was being carried on at the time the cultures were taken, which probably accounts for our failure to isolate the organisms on subsequent attempts.

In the treatment of the local lesions produced by torulæ in the mouth and pharynx excision of the local lesion, which has been advised by other writers, leaves a point open for criticism, as it opens an atrium for extension of the torulæ into the blood stream with the possibility of localization in remote parts. This danger is reduced somewhat if the excision is accompanied by means of the actual cautery, but usually such radical interference is neither necessary nor advisable. Oftentimes the location of the lesions precludes excision.

Potassium iodide by mouth in large doses seems to be effective in the treatment of localized torulosis, especially when used in conjunction with sodium iodide intravenously. We have employed as high as 120 gr. of potassium iodide orally in conjunction with 15 gr. of sodium iodide intravenously daily for a period of two weeks without harmful effect in a patient with a localized torulosis.

Iodine solutions may be applied locally, preferably as Lugol's solution or surgical solution of colloidal iodine, 3 per cent. Tincture of iodine has in our experience proven to be too escharotic for repeated applications.

The lesions should be treated with the x-ray in conjunction with other therapeutic measures. In the four cases we have had under our observation in which this form of therapy has been used there have been no fatalities, and in each instance the lesions have healed and the patients have remained free from recurrence.

When central nervous system involvement occurs all known therapeutic measures fail and the disease is invariably fatal. Jacobson[5] has advised the use of colloidal copper in torulosis because of the similarity of this disease to coccidoidal granuloma in which this drug has acted favorably, though no clinical cases of torula infection have been treated with it. In addition, this writer recommends the use of a torula vaccine, though he states he has not observed its effect in actual cases and apparently recommends it only on theoretical grounds.

X-ray has been, in our experience, invaluable in treating the local lesions, but it should not be used too intensively at one time. It is advisable to repeat the applications at intervals of from five to ten days. In surveying the literature on torulosis the impression has been gained that at least some of the reported cases have been treated too vigorously with radiant energy, such as the x-ray and radium. Radium has been tried on the local lesions by Berghausen[21] without marked benefit. The writer has had no experience with radium in the treatment of torulosis.

Local lesions of the mucous membrane of the upper respiratory tract, when proven to be torulosis, should be treated vigorously and early with iodine and iodides in conjunction with x-ray, if good results are anticipated. Valuable time may be lost in awaiting the report of the bacteriologist on the cultural reactions; therefore, if smears and curettings reveal the presence of yeasts, treatment should be immediate. Iodides should be administered in adequate dosage, both orally and intravenously, with iodine in some form locally. It is advisable to continue the internal administration of iodides for some time after all lesions have healed to guard against recurrences. Oftentimes torulæ may be isolated from the oropharynx by culture after the local lesions have healed.

It has been my privilege to observe four patients with torulæ infection of the upper respiratory tract which has in each instance been proven culturally. Their case histories will be briefly presented in this article with notes on their salient features. The youngest was twelve years of age, the eldest twenty-nine years. Two males and two females are represented. In one instance the cultures for torulæ were persistently positive for many months after the local lesions had healed. All four cases were similarly treated and there were no fatalities from the disease.

Biopsy in these four patients was purposely avoided to obviate the danger of generalized infection which might follow such procedure.

REPORT OF CASES.

CASE 1.—A. C., a white girl, aged 12 years, for two years and nine months immediately preceding her illness, had lived in the Hawaiian Islands. She was first examined August 19, 1926, at which time there was marked edema of both upper and lower eyelids of the right eye and a moderate degree of proptosis of the right eyeball. The mucous membrane of the nose was slightly reddened and the right nasal fossa was filled with pus. Her illness had its onset August 18 and was accompanied by malaise, slight frontal headache and a slight rise in temperature.

Her past history revealed the fact that she had been a frequent sufferer from sties. In 1920 she had measles and in 1925 chickenpox. She had been immunized against diphtheria, typhoid and smallpox.

When first examined her temperature was 102.6, pulse 128, and respiration 28. X-ray made on admission showed cloudiness of the right antrum. The blood picture revealed white blood corpuscles 24,800 per cubic millimeter with 91 per cent polymorphonuclear neutrophiles, 8 per cent mononuclear lymphocytes and one per cent large mononuclear lymphocytes. There were no eosinophiles or basophiles present. The urine showed one plus sugar. A tentative diagnosis of acute right orbital abscess was made.

Operation August 21 consisted of incision through the upper eyelid into the right orbit at the inner canthus which evacuated about 10 cc. of heavy brown pus.

A small drainage tube was inserted into the abscess cavity. Postoperative treatment consisted of irrigation of the abscess cavity with dilute iodine solution and the internal administration of potassium iodide, 120 gr. daily, with 15 gr. of sodium iodide intravenously once daily. Smears taken at time of operation revealed an occasional diplococcus and a great number of budding yeast like organisms, which later were classified as torulæ. The diplococcus was not classified. Throat smears were negative for Vincent's organisms and cultures negative for bacillus diphtheriæ. A blood culture taken August 20 was reported positive for torulæ. During the first postoperative week the patient was given one x-ray treatment to the right orbit and nasal accessory sinuses. The patient's general condition did not show much improvement during the first five postoperative days; the temperature remained around 101 and the blood count ranged from 18,200 with 82 per cent polymorphonuclear neutrophiles to 22,250 with 81 per cent polymorphonuclear neutrophiles. On August 25 it was decided to make an inferior meatal window into the right antrum and to open the anterior ethmoid cells through the previously made orbital incision. This was done under ether anesthesia. On the following day an indurated area appeared in the mucous membrane of the hard palate on the right side. Incision into this area evacuated a small quantity of heavy brownish colored pus. Within

Fig. 1. Case 1. (a) Showing appearance twenty-four hours after incision into right orbit at inner canthus to evacuate orbital abscess due to torula. (b) After recovery.

48 hours after opening the right anterior ethmoidal cells and the right antrum the patient's condition began to improve, the temperature dropped to 99. The blood count was 14,450 white blood cells with 82 per cent polymorphonuclear neutrophilic leucocytes. In one week the white blood count had fallen to 9,400 leucocytes, with 70 per cent polymorphonuclear neutrophilic leucocytes and the temperature had become normal. An x-ray of the chest August 23 revealed no deviation from normal. All urinalyses except the first revealed no pathologic constituents. On September 9 the blood count was 4,320,000 red blood cells, with 80 per cent hemoglobin, white blood cells 9,400, polymorphonuclear neutrophiles 70 per cent, small mononuclear lymphocytes 30 per cent with no large mononuclear lymphocytes, eosinophiles nor basophiles. The blood culture was repeated twice, but was negative each time.

On August 26 a small piece of tissue separated spontaneously from the wound orifice in the upper lid, which upon histologic examination proved to be partially necrotic fibrinous material densely infiltrated with leucocytes, but

no yeast cells were present. X-ray treatment was repeated at weekly intervals and the right antrum and orbital wound were flushed daily with dilute iodine solution. The patient improved progressively and on September 10 was discharged from the hospital. The wound in the right orbit did not completely heal until October 15. During the entire postoperative period the iodides were continued by mouth and intravenously. X-ray to the orbit and sinuses was given at weekly intervals during this time. Numerous physical and roentgenologic examinations of the chest failed to reveal any evidence of nervous system involvement. The patient has remained well up to the present time, a period of more than seven years following her illness.

CASE 2.—N. K. N., white, male, aged 29 years, was examined March 24, 1932, at which time he complained of intense pain in the throat and inability to take any nourishment except liquids. He had been treated by several physicians since the onset of his trouble in December, 1931, having received neosalvarsan intravenously, quartz light therapy, and other local applications, all with little benefit. His Wassermann reaction, February 28, 1932, was negative. Examination of the throat revealed ten ulcerative lesions involving the upper pole of the left tonsil and soft palate. Several of the lesions were confluent. There was considerable destruction of the upper pole of the left tonsil. The mucous membrane lesions

Fig. 2. Case 2. Artist's sketch of torula lesions involving upper pole of left tonsil, left side of soft palate and left side of uvula. There were ten lesions in all, several of which were confluent.

involved the entire thickness of the mucosa of the areas involved, but did not deeply invade the underlying muscle tissue. Curettings from these ulcers revealed yeast cells in abundance. All smears were negative for Vincent's organisms and bacillus diphtheriæ. The general physical examination failed to reveal any pulmonary involvement and neurologic examination, including eye grounds, revealed no signs of involvement of the central nervous system. The patient was somewhat emaciated due to his prolonged restricted intake of nourishment. The Wassermann test was repeated March 24, 1932, and was found to be negative. The blood picture at this time revealed red blood cells 4,768,000, hemoglobin 90 per cent, white blood cells 7,000, polymorphonuclear neutrophilic leucocytes 75 per cent, small mononuclear lymphocytes 18 per cent, large mononuclear lymphocytes two per cent, eosinophilic leucocytes three per cent, and basophilic leucocytes two per cent. A culture made from the curettings taken from the ulcerated area revealed the presence of torula. Potassium iodide was administered by mouth in 20 gr. doses three

times daily. The use of sodium iodide intravenously was contemplated but the patient refused intravenous therapy. X-ray was used to the throat at intervals of five days and immediately following the first treatment the patient experienced relief sufficient to enable him to take semisolid food for the first time in several weeks. A total of five treatments were given. By May 5 all the lesions had healed. It is now over two years since his treatment was begun and he is apparently in normal health, having had no recurrence.

CASE 3.—R. J. F., white, male, aged 26 years, was seen January 27, 1932, because of marked discomfort from ulcerations present in the throat. The patient had suffered from sore throat at intervals for two years past. Eighteen months prior to January, 1932, he had his tonsils incompletely removed by electrocoagulation, which failed to relieve the distress in his throat. Two Wassermann tests had

Fig. 3. Photomicrograph of torula in pure culture isolated from Case No. 2. The cells in this culture appear principally as the oval form. Several budding forms may be seen.

been made, both of which were negative. He had been given several doses of neosalvarsan without relief of the throat discomfort. He was extremely apprehensive about his condition.

Examination revealed numerous ulcers (fifteen or twenty) on the lateral wall of the pharynx which extended upward into the epipharynx and involved a mass of adenoid tissue present there. There was a moderate amount of mucopus in the epipharynx. The mucous membrane of the pharynx was somewhat hyperemic. General physical examination was negative except for the findings in the nose and throat and moderate loss of weight. Pus was present in the olfactory cleft on the left side. The ulcerated areas were covered with white exudate and in the center of some of these areas there was a black deposit which was at first thought

to be due to the prior application of nitrate of silver, but was later found to be due to pigment formed at the site of the lesion. One ulcerated area was detected on the inferior turbinate, left side, near its midportion. Cultures and curettings revealed the presence of budding forms which were subsequently classified as black pigment producing (chromogenic) torulæ. Smears were negative for Vincent's organisms and bacillus diphtheriæ. Potassium iodide was administered internally in twenty grain doses three times daily with local application of dilute iodine in the form of Lugol's solution once daily. A mouth wash containing iodine was also prescribed. X-ray therapy was immediately instituted and prompt improvement followed. The left antrum was lavaged several times through the normal ostium and each time a moderate amount of pus was removed, which did not show any budding forms on cytologic examination.

Unfortunately the patient refused to permit additional laboratory procedures which would make this case record complete. He has been under observation and treatment twenty-one months, and during this time there has been no recurrence of the local lesions, and the mucopurulent postnasal discharge has ceased. Cultures made from the mucous membrane of the pharynx and epipharynx on several occasions after the ulcers healed showed the presence of torula. The patient states that he feels much improved, but still insists that he has slight discomfort in his throat. A careful physical examination of his lungs on several occasions has failed to reveal any evidence of pathology. Unfortunately his nonco-operative attitude would not permit obtaining complete clinical data. His has been the most resistant case of torula infection which we have treated.

CASE 4.—Mrs. P. S., white, aged 27 years, was admitted to the Robert B. Green Memorial Hospital, March 6, 1932, to the Obstetrical Service, complaining of vomiting attacks which had been present for two days prior to admission, and which had become progressively worse since their onset until the time of admission at which time she was vomiting every ten or fifteen minutes. From her history and physical examination a diagnosis, seven and a half months' pregnancy and pre-eclamptic toxemia, was made. An attempt was made to overcome her toxemia by alkalies and restoring her fluid equilibrium, which resulted in temporary improvement. On March 11, it was deemed advisable to induce labor with a Pomeroy bag, and nineteen hours later on March 12, the patient was delivered of a male child. Immediately following delivery the patient's general condition was quite poor, but she quickly rallied with supportive treatment. On March 14, the patient expectorated a small amount of bloody sputum, and her general condition did not seem as good as it had been on March 12. Consultation was requested with the Ear, Nose and Throat Service at this time to determine the cause of an ulcerative lesion which was present in the patient's mouth, involving the hard palate on the right side in its midportion. Curettings from this ulcer revealed yeast cells in abundance. The ulcer was deep enough to expose the bone of the hard palate and in its center was a necrotic plug. The ulcer margins were elevated, but there was surprisingly little redness to the peripheral tissues. Cultures showed this yeastlike organism to be a torula. Potassium iodide was administered internally and x-ray treatments were given to the local lesion, and in a week the central necrotic mass was cast off spontaneously. During the patient's illness the urine examination revealed the presence of from one to three plus albumin on numerous occasions. Diacetic acid was present on admission, but not subsequently. Pus cells were present in the urine, and on one occasion an unclassified yeast was reported in the urine. Subsequent attempts to recover this yeast for cultural study were unsuccessful.

The blood picture revealed red blood cells ranging from 3,200,000 to 3,700,000, with hemoglobin from 65 per cent to 70 per cent; the leucocyte count varied from 5,100 to 8,000, with 76 per cent to 78 per cent polymorphonuclear neutrophiles, and 22 per cent to 24 per cent small mononuclear lymphocytes. No large mononuclear lymphocytes, basophiles or eosinophiles were present. Smears from the mouth were negative for Vincent's organisms, but positive for yeasts. The Wassermann reaction was negative on two occasions. Spinal fluid examination showed a cell count of seven lymphocytes per cubic millimeter, but was otherwise negative. The ulcer on the hard palate healed slowly and on March 30 the patient was discharged from the hospital. She has been observed at intervals since her discharge and there has been no evidence of pulmonary or nervous system involvement, nor has there been any return of the ulcerative condition in the mouth. X-ray of nasal accessory sinuses showed slight haziness of anterior ethmoids on both sides and of both maxillary antra, but no treatment other than shrinking sprays was used in the treatment of this condition.

CONCLUSION.

1. There is a localized form of torula infection involving the mucous membranes of the upper respiratory tract, which is amenable to treatment with iodine preparations and x-ray therapy.

2. The local form of torulosis may and probably does precede the more serious general invasion with localization in the viscera and central nervous system. It is probable that at this stage the infection is controllable in the majority of patients.

3. Pain is a prominent symptom in localized torulosis of the oral and pharyngeal cavities.

4. Excision, unless accomplished with the actual cautery, is inadvisable as there is increased danger of generalized invasion through opening of numerous atria for extension of the organisms into the general circulation. It is oftentimes impossible to employ excision because of the location of the lesions.

322 MEDICAL ARTS BLDG.

BIBLIOGRAPHY.

1. Miller, W. D.: Micro-organisms of the Mouth. Ed. 1, Philadelphia, S. S. White Dental Mfg. Company, 1890, p. 80.

2. Busse, O.: Sitzungsberecht des Greifswalder Med. Vereins, 3 Juni, 1894. Deutsche Med. Wchnschr., 1895, No. 3.

3. Busse, O.: Über Saccharomycosis Hominis. Virchows Arch. f. Path., Anat., 1895, 140, 23.

4. Nichols, E. H.: The Relation of Blastomyces to Cancer. J. Med. Res., 7:312, 1902.

5. Gilchrist, T. C.: A Case of Blastomycetic Dermatitis in Man. Johns Hopkins Hosp. Rep., 1:269, 1896.

6. Frothingham, L.: A Tumor-like Lesion in the Lung of a Horse Caused by a Blastomyces (Torula). J. Med. Res., 8:31, 1902.

7. Tanner, Fred W., and Dack, Gail M.: A Study of Yeasts from Sore Throats. Central bl. f. Bact., etc., 1:282 (May), 1924.

8. Jacobson, H. P., Schamberg, J. F., and Morrow, Howard: Fungus Disease. Chas. C. Thomas, Baltimore, Md., 1st Ed., p. 253, 1932.

9. Rogers, L. A.: A Fat Splitting Torula Yeast Isolated from Canned Butter (Abst.). Science, 17:370, 1903.

10. Klein, E.: Pathogenic Microbes in Milk. J. Hyg., 1:78, 1901.

11. Stoddard, J. L., and Cutler, E. C.: Torula Infection in Man. Monograph No. 6, Rockefeller Inst. for Med. Research, New York, 1916.

12. Sheppe, W. M.: Torula Infection in Man. A. J. Med. Sci., 167, 91, 1924.

13. Shapiro, L. L., and Neal, Josephine B.: Torula Meningitis. Arch. Neurol. and Psychiat., 13, 174-190, 1925.

14. Stone, Willard J., and Sturdivant, B. F.: Meningo-Encephalitis Due to Torula Histolytica. Arch. Int. Med., 44, 560-575, 1929.

15. Pierson, Philip H.: Torula in Man. J. A. M. A., 69:2179, Dec. 29, 1917.

16. Cornwall, Leon H., and McKendree, C. A.: Meningo-Encephalitis Due to Torula. Arch. Neurol. and Psychiat., 16:167, Aug., 1926.

17. Lynch, F. B., Jr., and Rose, Edward: Torula Meningitis. Ann. Clin. Med., 4:755, 1926.

18. Massee, J. C., and Rooney, J. S.: Meningitis Due to Torula Histolytica. J. A. M. A., 94:650-1953, 1930.

19. Rappaport, B. X., and Kaplan, B.: Generalized Torula Mycosis. Arch. Path. and Lab. Med., 50:720, May, 1926.

20. Watts, James W.: Torula Infection. Am. J. Path., 8:167, March, 1932.

21. Berghausen, Oscar: Torula Infection in Man. Ann. Int. Med., 1:235, Oct., 1927.

22. Jones, Lloyd: Torula Infection of the Palate and Nasopharynx. West Va. Med. J., 23:184, April, 1927.

23. Jones, Lloyd: Torula Infection of Nasopharynx. South. Med. J., 20:2-120, Feb., 1927.

24. Alvarez, Ruth Stone: A Red Torula as the Cause of a Tongue Abnormality—Report of a Case. J. A. M. A., 87:1358-1359, 1926.

25. Turck, W.: Ein Fall von Hefeinfektion (Saccharomykose) der Meningen. Deutsches Arch. f. klin. Med., 90:335, 1907.

26. Iglauer, Samuel: Pneumocele of the Frontal Sinus with Report of a Case, Probably Secondary to Blastomycosis. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 39:56, March, 1930.

27. Chavarrio, G. Pena: Algunas consideraciones clinicas sobre la blastomicosis de la mucosas nasobucofaringe, fundadas en observationes hechas en varios paiseo de America latina. Rev. Med. latino-amer., 13:1200-1302, 1928.

28. New, Gordon B.: Blastomycosis of Tongue. J. A. M. A., 68:186, Jan., 1917.

29. New, Gordon B.: Blastomycosis of Larynx. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 37:240, March, 1928.

30. New, Gordon B., and Childrey, John H.: Primary Blastomycosis of Tongue. Arch. Otolaryn., 12:184, Aug., 1930.

31. Jackson, Chevalier: Blastomycosis of Larynx. Arch. Otolaryn., 3:99, Feb., 1926.

32. Freeman, Walter: Torula Meningo-Encephalitis. Trans. Amer. Neurol. Assn., p. 203, 1930.

33. Hirsch, Edwin F., and Coleman, Geo. H.: Acute Miliary Torulosis of the Lungs. J. A. M. A., 92:437-438, 1929.

34. Healy, T. R., and Morrison, L. B.: Yeast Infection of the Lungs. Amer. J. Roent. and Rad. Ther., 26:408, 1931.

35. Altschul, F. J.: Blastomycosis with Pulmonary Involvement and Recovery. J. Med. Soc., N. J., Orange, 1930.

36. Avery, S. Fowler: Report of a Case of Pulmonary Blastomycosis with Recovery. J. Lancet, Minn., 51:289-290, 1931.

37. Craik, Robert: Brit. Med. J., April, 1929. Quoted by Norris, J. C. (ibid.).

38. Brewer, G. E., and Wood, F. C.: Blastomycosis of the Spine. Double Lesions. Two Operations. Recovery. Ann. Surg., 48:889, 1908.

39. Weidman, F. D.: Cutaneous Torulosis. South. Med. J., 26:851-863, Oct., 1933.

40. McGehee, J. L., and Michelson, I. K.: Torula Infection in Man. Surg., Gyn. and Obst., 42:803, 1926.

41. Verse: Über einen Fall von generalis ierter Blastomykose beim. Menschen. Verhand d. Deutsch. path. Gesellsch., 17:275, 1914.

42. Urbach, E., and Zach, F.: Generalized Torulosis. Arch. für Dermat. u. Syph., 162:401, 1930.

LXIX.

CICATRICIAL ATRESIA OF THE ESOPHAGUS.*

HAROLD LESLIE KEARNEY, M. D.,

NEW ORLEANS.

Atresia,—imperforation; absence or closure of a normal opening. Stricture,—the abnormal narrowing of a canal, duct or passage, either from cicatricial contraction or the deposit of abnormal tissue. Stenosis,—narrowing or stricture of a duct or canal. (Dorland's Medical Dictionary.) One often hears these terms—atresia and stricture or stenosis—used loosely in the description of complete cicatricial closure of the esophagus. Cicatricial atresia is exactly descriptive of the condition.

The subject of this presentation is limited to atresia of the esophagus resulting from cicatricial changes. The etiologic factors in cicatricial atresia of the esophagus are the same as in cicatricial stenosis of the esophagus. The most common cause is the swallowing of chemical escharotics, usually lye but fairly commonly, acids. Other causes are systemic diseases complicated by esophageal lesions, among which may be mentioned scarlet fever, diphtheria, typhoid fever, tuberculosis and syphilis. Esophageal trauma from wounds, foreign body or surgery may be followed by local infection resulting in chronic cicatricial changes. Cicatricial atresia of the esophagus is comparatively rare. As pointed out by King,[1] many cases referred to as impermeable because of failure of ordinary bouginage, later are passed by string swallowing or some other method which discloses that the strictures are not really impassable. I have observed in a patient who swallowed lye that esophageal atresia, as shown by skiagraph and esophagoscopy, may prove to be temporary and open up as a small lumen stricture when the esophagus is placed at rest by gastrostomy. In such cases the stricture is closed by the inflammatory swelling from esophagitis and not by a cicatrix.

With modern methods of treatment the problem of management of cicatricial stenosis of the esophagus is simple and the mortality from the condition, when properly treated, is extremely low.

---

*Presented as a candidate's thesis to the American Laryngological, Rhinological and Otological Society, 1935.

I have not had a death from this condition. In atresia of the esophagus, on the other hand, the tehnical problem of restoration of the esophageal lumen is tremendous, and even with the utmost care and skill the hazard to the patient's life is great. These unfortunates may, therefore, be wisely advised to go through life with gastrostomic feeding rather than undergo the risk of operative interference designed to restore the esophageal lumen or to fashion a new esophagus. Particularly dangerous is the attempt to restore esophageal lumen in those cases with cicatricial atresia of the middle third of the esophagus. This comparison of the gravity of esophageal atresia, as contrasted with esophageal stenosis, emphasizes the importance of two measures for prophylaxis—first, the campaign, so ably sponsored by Chevalier Jackson,[4] for proper labeling of lye containers; second, the proper early management of cicatricial stenosis of the esophagus so that atresia cannot develop. In any case of cicatricial stenosis of the esophagus of such degree as to limit the diet to liquids, the patient should be required to swallow a string and he should be promptly placed under the care of a physician trained in the management of these cases. With the esophagus threaded by a string, atresia cannot develop and the stenosis can be satisfactorily treated. My own practice in small lumen cicatricial stenosis of the esophagus is to have gastrostomy done to promote esophageal rest and to permit treatment by retrograde bouginage after the method of Tucker,[14] in which the continuous string insures against esophageal closure in those all too frequent cases in which the patient is not brought back regularly for treatment.

Cicatricial atresia of the esophagus may develop at any level, but is more commonly found in the middle third of the esophagus, as it is here that cicatricial stenosis of the esophagus most often develops. Of the three cases here reported, one was near the cricopharyngeus and the other two were in the middle third. Chevalier Jackson[5] and St. Clair Thomson[13] report the order of frequency of cicatricial stenosis of the esophagus as at the crossing of the left bronchus, near the cricopharyngeus and at the hiatal level. I have been unable to find a case of multiple cicatricial atresia of the esophagus recorded in the literature, but since cicatricial stenosis of the esophagus is frequently multiple it is probable that cicatricial atresia of the esophagus may sometimes be multiple. In such a case, with separate points of atresia, esophageal lumen would be present between the points of closure. In solitary atresia the esophageal lumen may be obliterated for a few millimeters or for several centimeters. King describes the atresia in his case as appearing to be one-half to three-

quarters of an inch in thickness.[8] Wishart and Briggs also describe the atresia in their case as being apparently of one-half to three-fourths of an inch in extent.[16]

TYPES OF OPERATIVE PROCEDURE FOR RELIEF OF CICATRICIAL ESOPHAGEAL ATRESIA.

1. Endoscopic penetration from above against the surgeon's finger introduced into the esophagus from below.[16 3] This method is applicable only in atresia of limited extent located low enough in the esophagus to be reached by the surgeon's finger introduced through the stomach.

2. Penetration through combined peroral and retrograde endoscopy with fluoroscopic guidance.[8 5] This method can be used for atresia at any point in the thoracic esophagus provided the atresia is of limited extent[6] and can be reached by retrograde esophagoscopy.

3. Esophagoplasty by the abdominal route, as described by Lambert.[9] Turner has done esophago-gastric anastomosis successfully in four cases by the abdominal route, and in one case, with a small lumen stricture of the extreme lower end of the esophagus, he did a successful esophagogastric anastomosis by the thoracic route.[15] He expresses preference for the abdominal route as being technically easier and less hazardous. After exposure of the abdominal esophagus through xipho-umbilical laparotomy, he is able after finger dissection to draw two or more inches of the thoracic esophagus into the abdomen. Gregoire[2] prefers the combined thoraco-abdominal route in cardiospasm and allied conditions and does a large splitting of the diaphragm from behind forward for exposure of the lesion. Bircher[1] uses cardio-esophageal anastomosis in cardiospasm when dilatation has failed. Lusena[10] uses abdominal esophagogastrostomy when surgery is required for mega-esophagus. Sauerbruch[11] has done twelve esophagogastric anastomoses without a death. Soupalt[12] emphasizes the facility of access to the lower esophagus by xipho-umbilical laparotomy. With the above methods it is conceivable that esophagogastric anastomosis could be used for atresia of the extreme lower end of the esophagus.

4. Antethoracic esophagoplasty, as pointed out by Jiano,[7] is to be considered only if the esophagus can be of absolutely no service, if other methods have failed and if the patient does not wish to keep a permanent gastrostomy. In this method Jiano prefers to use a short jejunal loop, well nourished and free from danger of kinking, and uses a cutaneous tube to bridge the gap between the end of the jejunal segment and the stump of the cervical esophagus brought out

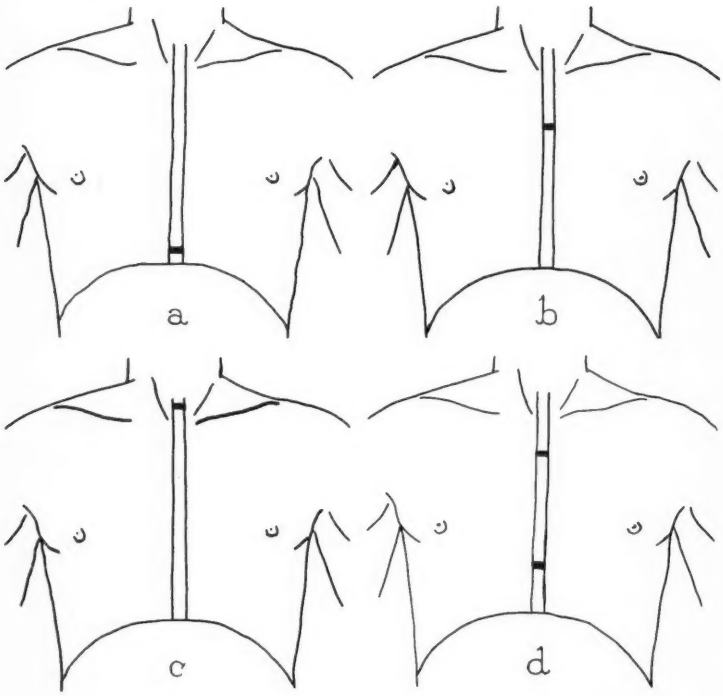

Fig. 1. Diagrams illustrating various types of cicatricial atresia of the esophagus.

a. Extreme lower end of esophagus; procedure 1, 2, 3 or 4 may be used.
b. Middle third of esophagus; procedure 2 or 4 may be used.
c. Cervical esophagus; procedure 5 may be used.
d. Multiple atresia of esophagus with esophageal lumen between two points of closure. Procedure 4 may be used, or with visualization of the esophagus between the points of closure by the method herein suggested, procedure 2 could be used.

at the neck. When completed, the newly fashioned esophagus is a subcutaneous, presternal affair extending from the stump of the cervical esophagus at the neck to the abdomen, where it connects with the stomach. Jiano cites eighty-five cases, twelve of which died and sixty-five were cured.

5. In cicatricial atresia of limited extent, located high in the cervical esophagus, the lesion is accessible to direct surgical approach through the neck.

The penetration of cicatricial esophageal atresia of the middle third of the esophagus under double plane fluoroscopic guidance is always hazardous, but in atresia of more than a limited extent it is too hazardous to warrant consideration because of the lack of a guide. With the belief that with widely separate points of atresia there may be esophageal lumen between the two points of atresia, I have attempted to devise a method for the fluoroscopic visualization of this cyst-like esophageal remnant. Cyst-like, because its lumen would be filled by secretion from glands in the esophageal mucosa. With this in mind, a special needle for use through the esophagoscope was constructed with the idea of puncturing, under fluoroscopic control, through the lower point of atresia into the cyst-like esophageal segment and injecting a radiopaque substance for x-ray visualization of the esophagus between the two points of atresia. Then, in theory, the sheath is advanced to cover the needle point, thus enabling the instrument to slide along in the closed off esophageal lumen as would a bougie. On arriving at the upper point of atresia the sheath is retracted to again expose the needle, which is then made to penetrate into the peroral esophagoscope. A wire is then passed through the needle and drawn up into the mouth. The needle is removed, leaving the wire in place. A thread is firmly attached to the lower end of the wire by means of a special chuck and the esophagus threaded by pulling up the wire. The possibility, indeed the probability, of injecting the radiopaque substance into the mediastinum was keenly realized. Some comfort was gained in this regard by the knowledge of a case in which lipiodol was accidentally injected into the mediastinum during an attempt at pneumonography by the transcricothyroid membrane route, in which no harm resulted.

Attempt to visualize the esophageal remnant was made in case 1, using lipiodol as a contrast medium. Although the effort was unsuccessful, no harm resulted to the patient, and this report is made with the hope that the method may be found useful. A more suitable contrast medium would be an improvement. The lipiodol in the case reported has not been absorbed after five years, and some absorbable contrast medium would be better, as it would not be a source of error in case the procedure were repeated.

If penetration of double points of esophageal atresia is to be attempted in two stages, either retrograde endoscopic attack or surgical attack should be done first on the lower point because of the comparative sterility of the gastric secretions as contrasted with the gross contamination of the mouth secretions.

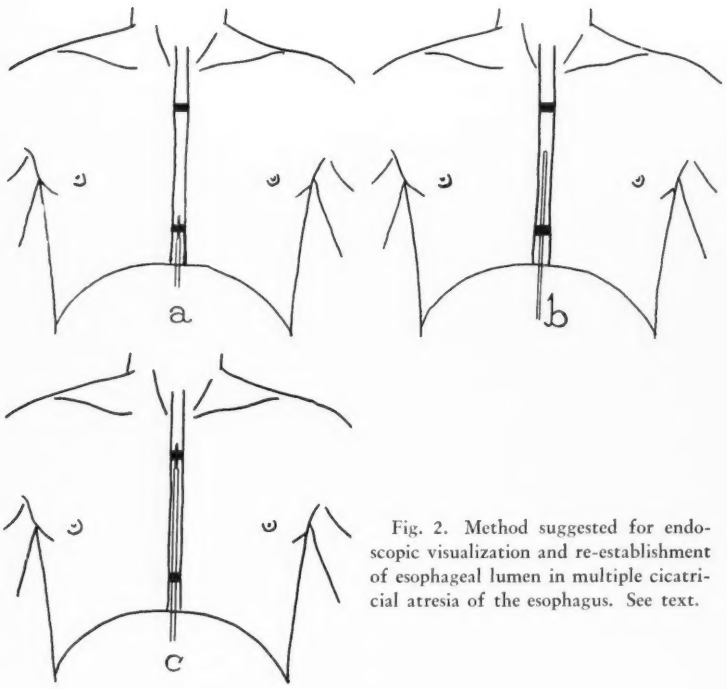

Fig. 2. Method suggested for endoscopic visualization and re-establishment of esophageal lumen in multiple cicatricial atresia of the esophagus. See text.

REPORT OF CASES.

CASE 1.—W. S. swallowed lye February 17, 1923, at the age of two and one-half years. Complete esophageal obstruction developed and he was brought to Dr. Rudolph Matas, who did a gastrostomy for him at Touro Infirmary, May 13, 1923, and referred him to me. However, he was removed from the hospital before either esophageal examination or treatment could be done and was not seen again for six years, when in 1929 he was readmitted to the hospital.

In the interim he had been unable to swallow anything whatever except for a brief period in 1927, when, after a severe attack of measles, his esophagus opened sufficiently for him to take all his nourishment by mouth, even such food as cucumbers. At this time his mother took him elsewhere to have the gastrostomy closed. Instead of this, a bougie was passed blindly and the esophagus again closed.

His age on his second admission to the hospital was eight and one-half years and his weight was twenty-four pounds. Under a proper dietetic regimen his weight and strength increased. String swallowing was tried, but despite many attempts the thread never appeared in the stomach. February 22, 1929, esophagoscopy showed cicatricial atresia of the esophagus eighteen centimeters from the upper incisor teeth. Retrograde esophagoscopy was done March 4th, and showed the characteristic funnel shape of the esophagus below a point of atresia about one

Fig. 3. Skiagraph of case 1. Barium marks the upper limit, and the end of the radiopaque bougie marks the lower limit of esophageal atresia. The white shadow near the bougie is lipiodol which was introduced in an unsuccessful effort to visualize the esophagus between the two points.

inch above the diaphragm. A radiopaque bougie was passed upward to the point of atresia. The child was then given barium by mouth and x-ray examination done by Dr. W. F. Henderson, who reported as follows:

"The administration of the opaque substance by mouth shows this to come to rest approximately at the angle of Lewis, while a retrograde esophagoscopy shows the opaque bougie coming to rest at such a point that six centimeters exists between the tip of the bougie and the previously administered opaque substance. It is considered that there is an absolute atresia of six centimeters in length involving this esophagus."

In view of these findings I felt that the fluoroscopically controlled method of penetration through combined peroral and retrograde esophagoscopy was too hazardous to warrant consideration in my hands and sent the patient to Dr. Chevalier Jackson for consultation and treatment if he deemed it advisable. Dr. Jackson very kindly saw the patient and gave us some valuable advice about his management. He concurred in my opinion that the hazard of operation was too great to warrant its consideration.

Then, in thinking over the hypothesis that there is in some of these cases of distant points of cicatricial esophageal atresia, an intervening length of esophagus with normal lumen, I conceived the idea of puncturing into this lumen through the retrograde esophagoscope and attempting to outline this esophageal segment by means of an injected radiopaque substance. If this were successful it would facilitate the fluoroscopic control of an instrument penetrating from one point of atresia to the other. Accordingly, under fluoroscopic control, the lower point of atresia was penetrated for a distance of about one and a half centimeters by means of a needle (Fig. 2) introduced through the retrograde esophagoscope and about one and a half cc. of lipiodol injected. Under the fluoroscope this seemed to pass upward in the course of the esophagus, but an x-ray picture made immediately showed that the lipiodol had failed to enter the esophagus and was in the mediastinum. The possible causes of failure are covered by the following factors: 1. There may have been no closed off esophageal lumen present; 2. The needle was properly directed, but did not penetrate far enough to enter the closed space; 3. The needle was misdirected.

The patient complained of pain during the injection and for the ensuing two minutes, after which he said he felt all right, was smiling and in good humor. His discomfort seemed considerably less than that usually associated with the giving of antitoxin. No reaction of any kind whatsoever ensued, either at the time or within the five years following, during which the patient has been under observation. Five years after injection, skiagraph showed the lipiodol to be still present.

This patient has no drooling of saliva. He is happy, fairly well nourished and is able to do useful manual work. He is poorly developed, partly from heritage and partly from poor dietetic management in childhood.

CASE 2.—S. M., a white female, age 26, was seen May 5, 1927, in consultation with Dr. S. M. Blackshear. She had swallowed hydrochloric acid about one month before. For the past three days she had been unable to swallow even liquids. Fluoroscopic examination was unsatisfactory, as the patient could not swallow the barium mixture. Esophagoscopy showed cicatricial atresia of the esophagus at the level of the cricoid. Gastrostomy, done two days later, by Dr. Russell Stone, disclosed a gastric perforation through which the gangrenous mucosa of the stomach protruded and came away entire as a foul smelling necrotic mass. The patient died nine hours later.

Fig. 4. Skiagraph showing cicatricial esophageal atresia of forty years' duration. Case 3.

CASE 3.—C. B., a carpenter, white, male, age 47, was referred by Dr. Rudolph Matas. This man swallowed lye in 1894, at the age of seven, and gastrostomy was done by Dr. Matas eight months later. Complete occlusion of the esophagus developed and he has fed himself by gastrostomy for forty years. He uses a black, gum rubber gastrostomy tube with an inside diameter of one centimeter. Through this he is able to take practically any kind of food. He is happy, well physically and is too well satisfied with his gastrostomy to want surgery done to re-establish mouth feeding. He has no drooling of saliva and expectorates only when he chews tobacco. He has been free from pulmonary troubles.

CONCLUSIONS.

1. Cicatricial atresia of the esophagus should not develop if cicatricial stenosis is properly treated.

2. Cicatricial atresia of the middle third of the esophagus is the most difficult and hazardous type in which to re-establish esophageal lumen.

3. In an attempt to re-establish esophageal lumen in cicatricial atresia, the retrograde approach has the advantage that in case of failure the mediastinum has not been exposed to infection from the grossly contaminated mouth secretions.

4. Gastrostomic feeding is compatible with long life and useful employment.

5. In long established complete esophageal obstruction salivary secretions are diminished to a point where drooling does not occur.

6. Antethoracic esophagoplasty should not be done without thorough preliminary endoscopic and skiagraphic study. A perusal of the literature will show a number of cases in which this surgery has been done for small lumen strictures which could have been treated successfully by retrograde esophageal bouginage.

204 MEDICAL ARTS BLDG.

BIBLIOGRAPHY.

1. Bircher, E.: Etat Actual de la chirurgie de l'oesophage. IX Congres de la Societe Internationale de Chirurgie. Presse med., 1:511-513, April, 1932.

2. Gregoire, R.: Etat Actual de la chirurgie de l'oesophage. IX Congres de la Societe Internationale de Chirurgie. Presse med., 1:511-513, April, 1932.

3. Imperatori, C. J.: Complete Atresia of the Esophagus. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 40:1194, December, 1931.

4. Jackson, Chevalier: Peroral Endoscopy and Laryngeal Surgery. Laryngoscope Co., p. 522, 1915.

5. Jackson, Chevalier: Bronchoscopy and Esophagoscopy. Ed. I, Philadelphia. W. B. Saunders Co., p. 252, 1922.

6. Jackson, Chevalier: Bronchoscopy and Esophagoscopy. Ed 2, Philadelphia. W. B. Saunders Co., p. 350, 1927.

7. Jiano, J.: Etat Actual de la chirurgie de l'oesophage. IX Congres de la Societe Internationale de Chirurgie. Presse med., 1:511-513, April, 1932.

8. King, Edward: A New Method of Restoring the Lumen in a Case of Impermeable Stricture of the Esophagus. Surg., Gynec and Obst., 39:596, November, 1924.

9. Lambert, Adrian V. S.: Treatment of Diffuse Dilatation of Esophagus by Operation. Surg., Gynec. and Obst., 18:1-9, January, 1914.

10. Lusena, G.: Etat Actual de la chirurgie de l'oesophage. IX Congres de la Societe Internationale de Chirurgie. Presse med., 1:511-513, April, 1932.

11. Sauerbruch, F.: Etat Actual de la chirurgie de l'oesophage. IX Congres de la Societe Internationale de Chirurgie. Presse med., 1:511-513, April, 1932.

12. Soupalt, R.: Etat Actual de la chirurgie de l'oesophage. IX Congress de la Societe Internationale de Chirurgie. Presse med., 1:511-513, April, 1932.

13. Thomson, Sir St. Clair: Diseases of the Nose and Throat. Ed. 3. New York: D. Appleton & Co., p. 647, 1926.

14. Tucker, Gabriel: Cicatricial Stenosis of the Esophagus, with Particular Reference to Treatment by Continuous String, Retrograde Bouginage with the Author's Bougie. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 33:1180-1223, December, 1924.

15. Turner, George Grey: Some Experiences in the Surgery of the Esophagus. New England J. Med., 205:657-674, October, 1931.

16. Wishart, J. N., and Briggs, W.: A Case of Complete Cicatricial Stricture of the Esophagus. J. Laryngol. and Otol., 47:464, July, 1932.

LXX.

PARALYSIS OF THE LARYNX: A SUGGESTED EXPLANATION OF THE SO-CALLED CONTINUED MEDIAN POSITION OF THE VOCAL CORDS IN BILATERAL PARALYSIS—A CONSIDERATION OF SEMON'S LAW.*

CHARLES J. IMPERATORI, M. D.,

NEW YORK.

An explanation of the so-called sustained or continued median position of the vocal cords in bilateral abductor paralysis is presented purely on an anatomic basis.

Paralysis of the vocal cords following injury to the recurrent laryngeal nerve results in one of two conditions.

First, adduction with the vocal cords straight in the median line, or secondly, the cord is found in the cadaveric position—that is, midway between adduction and complete abduction.

New[1] has shown the reverse of this—that is, following injury to the recurrent laryngeal nerve, the cord assumes the cadaveric position and after several months approaches the midline position.

Ziegelman[2] has confirmed by dissections the findings of other anatomists, that the internal branch of the superior laryngeal nerve sends branches, which communicate with the recurrent laryngeal and that, contrary to the usual teaching, in most instances the arytenoid muscle is supplied by the superior laryngeal.

Burger[3] states that the nerve supply of the adductors is both the recurrent and the superior laryngeal.

It may be, therefore, assumed that in those persons who possess this innervation of the arytenoid muscle and in whom the recurrent nerve is injured, that there would occur a paralysis of the posterior cricoarytenoid muscle inducing adduction—that is, phonatory position of the cords.

---

*Presented before the annual meeting of the American Laryngological Association at Toronto, Ontario, May 29, 1935.

In those persons who possess the usual innervation they would have a complete paralysis—that is, the cords would be abducted and be in the cadaveric position.

Based on this anatomic fact, it is easily conceived that adduction of the cords would remain constant in those cases in which this innervation of the arytenoid muscle was present.

Assuming that the recurrent nerve is injured and the superior laryngeal nerve does not innervate the arytenoid, then the cord will assume the cadaveric position, but if the superior laryngeal does supply the arytenoid muscle, there will be sufficient adduction to keep the cords in partial contact, assisted by the cricothyroid, which is also innervated by the superior laryngeal. The tensing and adduction of the cricoid and arytenoid and thus keep the cords in the straight midline position, assuming that the other adductors are paralyzed.

This position of continued adduction is not so uncommon.

New and Childrey[4] conclude

"1. Usually paralyzed vocal cords in the cadaveric position change from this position to the median line within a few months, with return of voice. If the condition is bilateral, dyspnea develops as the voice improves.

"2. Vocal cords in the median line may return to complete function, but most of them remain in the median line.

"3. None of the vocal cords observed in the median line change to the cadaveric position."

They are of the opinion that the paralyzed cord moves from the cadaveric position to the midline position because of paralysis of the superior laryngeal nerve.

Smith, Lambert and Wallace[5] do not agree with New and Childrey that a concurrent superior nerve paralysis is present. They have found in a series of cases that thirty-three were in the median position and eighty-three in the cadaveric.

Lemere's[6] experiments have shown that section of the recurrent laryngeal nerve produces little change in the glottic picture, excepting the mobility of abduction, and that the cricothyroid tends to stretch the cords anteroposteriorly and draws them toward the midline, also that the arytenoid muscle assists in this adduction. He

denies that the superior laryngeal plays a part in this paralysis, but acknowledges that the fibers of the superior laryngeal run through the arytenoid muscle.

He has demonstrated that blocking the superior laryngeal nerve with alcohol or novocain in those patients with bilateral abductor paralysis gives considerable relief from the accompanying dyspnea. This relief he attributes to relaxation of the cricothyroid muscle.

When the superior laryngeal innervates the arytenoid muscle undoubtedly the relief will be greater.

CONCLUSIONS.

In many individuals the arytenoid muscle is innervated by the superior laryngeal nerves.

In no way does this suggested mechanism of continued adduction interfere with Semon's law.[7]

This law of Semon's deals entirely with the abductor fibers of the recurrent laryngeal in that they become affected sooner than the adductor fibers.

Lemere[8] has shown that the abductor muscles possess more lipoid granules in them than the adductors and that they are more susceptible to trauma.

A total paralysis, so called, with the vocal cords in the cadaveric position would seem to consist of a paralysis of the posterior crico-arytenoid muscles and the innervation of the arytenoid muscle by the recurrent laryngeal nerve.

A sustained midline position of the cords would consist of a paralysis of the posterior crico-arytenoid and the innervation of the arytenoid muscle by the superior laryngeal nerve.

The arytenoid muscle, assisted by the cricothyroid muscle, both innervated by the superior laryngeal nerve, thus sustain the cords in the position of adduction.

Clinically this appears to be so, for in abductor paralysis, with the cords in adduction, there is considerable relaxation and lessening of the dyspnea when the superior laryngeal nerve is blocked by the injection of novocain or alcohol, thus interfering with this nerve's action.

108 East 38th St.

BIBLIOGRAPHY.

1. New, G. B.: Laryngeal Paralysis Associated With Jugular Foramen Syndrome and Other Syndromes. Am. J. Med. Sc., May, 1923.

2. Ziegelman, E. F.: Laryngeal Nerves. Arch. Otolaryn., 18:793-808 (Dec.), 1933.

3. Burger, H.: Associated Paralysis of the Vocal Cord (Semon Lecture, 1933). Laryngology and Otology, 49:1 (Jan.), 1934.

4. New, G. B., and Childrey, J. H.: Paralysis of the Vocal Cords. Arch. Otolaryn., 16:143 (Aug.), 1932.

5. Smith, A. B., Lambert, V. F., and Wallace, H. L.: Paralysis of Recurrent Nerve. Edinburgh M. J., 40:344-354 (July), 1933.

6. Lemere, F.: Innervation of the Larynx. Arch. Otolaryn., 18:413-424 (Oct.), 1933.

7. Semon, Felix: Clinical Remarks on the Proclivity of the Abductor Fibers of the Recurrent Laryngeal Nerve to Become Affected Sooner than the Abductor Fibers or Even Exclusively, in Cases of Undoubted Central or Peripheral Injury or Disease of the Roots or Trunks of the Pneumogastric Spinal Accessory or Recurrent Nerves. Arch. Laryn., 2:197, 1881.

8. Lemere, Frederick: Innervation of the Larynx, IV: An Analysis of Semon's Law. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 43:537 (June), 1934.

LXXI.

THE USE OF FREE METALLIC SILVER IN THE NOSE.

LYLE S. POWELL, M. D.,

LAWRENCE, KANSAS.

The occasional problem of intranasal synechiæ has always been a difficult one. The following successful solution was devised after much experimentation with defferent methods.

A piece of the darkest portion of an exposed developed x-ray film is cut off and shaped with the scissors into a long eliptical plate. The size varies with the capacity of the individual nose, but it is usually made about 3 inches long, 1⅛ inches wide at the large end and ⅞ inches wide at the narrow end. The nose is mildly cocainized and the synechia divided. The nasal speculum is placed in the vestibule of the nose with one lip of the speculum resting on the floor of the nose, the other lip of course being directly above it. The eliptical film plate is taken in the right hand and bent slightly together along its long axis. The small end of the plate is then placed in the nose with its edge resting on the metallic lip of the speculum and with the convexity of the plate toward the lateral aspect of the nose. The plate is then slid quickly into the nose, keeping the edges of the film always on the metal lips of the speculum. The moment the large end of the plate enters the nose, the film plate straightens out again and lies along the floor of the nose in a vertical position, completely separating the inferior turbinate from the septum.

The patient is advised that there may be some sneezing for the first few minutes and that after that he will scarcely be aware of their presence. The plates are left in until the film becomes perfectly white, which is usually about one week. There is no possibility of the plate escaping anteriorly through the nose or posteriorly into the nasopharynx. In removing the plates the same technic is followed. The plate must be grasped with dressing forceps and bent together on its long axis to permit its free and painless exit through the vestibule of the nose.

After using these plates in a number of cases such marked improvement was noted in the general appearance of the mucosa of the nose, particularly of the inferior turbinate, that the plates were

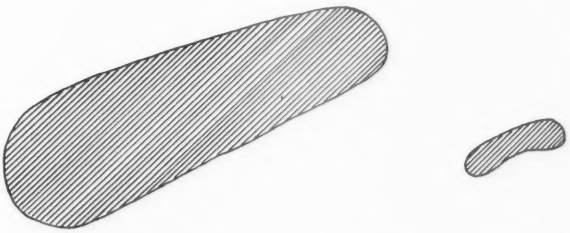

Fig. 1. Shape of plates used in the nose and ear. The size varies with nature of each case. This diagram is approximately 2/3 actual size.

tried in a number of cases of boggy turgescent inferior turbinates without synechiæ. Again marked improvement was noted, the bogginess and turgesence disappeared and the mucosa of the nose became quite normal in appearance. It has become a very valuable adjunct in the treatment of selected chronic nasal cases.

Application of the same method to the after care of the radical mastoid cavity has been reported to me,* with excellent results. A small, bean-shaped plate is cut, bent slightly at its center, and placed across the facial ridge, concave edge outward. The tendency to adhesion and webbing to the ridge is readily controlled. It is allowed to remain in the cavity one week.

The x-ray film consists of celluloid covered with a gelatin emulsion containing a silver salt, usually silver bromide, sometimes with a small amount of silver iodide. When the film is developed, the reducing agent leaves free metallic silver on the celluloid. This metallic silver is slowly absorbed by the mucosa of the inferior turbinate and septum. The advantages of a continuous contact supply of free silver to the chronically inflamed nasal mucosa are thus made possible without irritation or discomfort to the patient and without any of the violent reactions occasioned by the single or repeated applications of a silver salt solution.

833½ Massachusetts St.

*Personal communication from Dr. James B. Costen, St. Louis, Mo.

Symposium
Before the American Otological Society, Toronto, May 27, 1935

SUBJECT: IS THERE LOCALIZATION IN THE COCHLEA FOR LOW TONES? IS IMPAIRED HEARING FOR THE TONES BELOW 1000 D. V. EVER DUE TO A COCHLEAR OR INNER EAR LESION; IF SO, WHERE IS THE LESION LOCATED AND HOW IS IT RECOGNIZED CLINICALLY?

It is generally accepted that impaired hearing for the tones below 1,000 d.v. is usually due to some condition in the middle ear that interferes with the movements of the ossicles. When impaired hearing is due to a middle ear lesion the Weber test is localized to the side with the poorer hearing, bone conduction is better than air conduction and bone conduction is not shortened.

There is a large group of cases in which the hearing for the low tones as well as the high tones is impaired; the Weber test is lateralized to the better hearing ear, air conduction is better than bone conduction and bone conduction is markedly shortened or entirely absent on the affected side. Many patients with this type of hearing defect have attacks of vertigo and are classified as Ménière's Symptom Complex; in many others the only symptom is impaired hearing. The text books ascribe these symptoms to a toxic neuritis of the auditory nerve. Our knowledge of the pathology associated with this clinical picture is practically nil when compared with our knowledge of the causes of middle ear deafness.

The purpose of this symposium was to bring together with the clinical otologists, the physiologists in this country who have correlated histological lesions and hearing acuity in man, and those who have studied the effect of experimentally produced lesions in the cochlea of animals. It is hoped that in this way we may learn something about the interpretation of hearing tests that will be of value to the otologist in his clinical work.

I. INTRODUCTORY REMARKS BY THE PRESIDENT.

LXXII.

SAMUEL J. CROWE, M. D.,

BALTIMORE.

Some of our members have made the criticism that the programs of this Society are becoming too scientific and are "over the heads" of a large percentage of the audience. This may be a just criticism. Scientific investigation is a search for the truth, and the reward every investigator hopes for is that he will some day be able to make a discovery of great practical importance. A series of isolated facts gained by the arduous labor of a multitude of workers is gradually pyramided, eventually correlated by some individual, and a new discovery is announced to the world. This is the story of insulin, the thyroid, the parathyroids and the hypophysis. This is the only road by which advances in otology may be made. There must be some society in this country before which those engaged in scientific investigations of the physiology of the ear and the disorders of hearing can present their work. The logical place is the American Otological Society. If this Society is to fulfill its obligations and justify its existence it must do everything in its power to stimulate and encourage all investigation that will broaden our knowledge of the ear. Of equal importance to the Society and to the investigators, however, is the fact that new work and new methods must be presented in a way that will educate and interest those of us engaged in active clinical work.

Your officers have given serious consideration to these criticisms and have adopted for this year the plan of asking a group of men engaged in scientific investigations of the ear to co-ordinate their work and present it in the form of a symposium, rather than as a series of papers on any subject in which they may be most interested at this particular time. The subject chosen for the first symposium of this kind was "The Function of the Apical Turns of the Cochlea and the Symptoms of a Lesion in This Location." In June, 1934, a letter was sent to the anatomists, physiologists and psychologists present today, outlining the plan for this symposium and asking if they would direct their work during the next year toward a solution of this problem and present their results at the 1935 meeting of this Society. It is greatly to their credit and is evidence of the co-operative spirit of scientific men in this country that every man agreed to

pool his work, even though it disrupted the plans for his own investigations. The answer to this question about the physiology of the cochlea, and particularly about the localization for low tones, is of great practical importance in the interpretation of clinical tests of hearing. The ultimate aim of all otologic investigation is to enable the clinician, by his tests, to visualize the exact location and nature of the lesion causing the impairment of hearing. It is of no value to make audiometric and tuning fork tests unless they can be intelligently interpreted.

Practically nothing is known about the location of the lesion causing a type of impaired hearing, commonly encountered in otologic practice, in which both low and high tones are involved, air conduction is better than bone conduction and the perception by bone conduction is either much shortened or entirely absent. This type of hearing impairment is often ascribed to a "toxic neuritis" of the cochlear nerve. So far as I know, there is no histologic or pathologic justification for the diagnosis of "toxic neuritis." It may be that the "toxic" changes in the nerve are not visible under the microscope, but before accepting this explanation and the diagnosis of toxic neuritis, every investigative method at our disposal must be utilized in an effort to learn more about this type of hearing defect.

This is the object for the first symposium on our program today. We are grateful to our distinguished guests for coming here and taking part in this program. I am sure that we will all be stimulated and will learn something new about the mysteries of the organ of hearing.

II. DISCUSSION FROM THE POINT OF VIEW OF STUDIES ON HUMAN TEMPORAL BONES.

LXXIII.

By Stacy R. Guild, Ph. D.,

Baltimore.

The subject that is the topic for our symposium today has an enormous literature. Numerous theories of hearing and modifications of these theories have been published, and but very few factual observations. I shall not attempt to give even a brief summary of the theoretical literature on hearing, for the reason that, in my opinion, it would add nothing but confusion to our discussions. The great

need at present, in this field, is more facts: there has been more than enough theorizing.

The factual literature, so far as localization for low tones is concerned, consists almost entirely of reports of animal experimentation, and therefore falls outside the phase of this symposium that I have been asked to present. Some of these reports are very pertinent to the problem, and I trust that other speakers today will introduce the evidence already thus obtained.

I shall limit myself to presenting evidence afforded by observations on the human, and primarily to that obtained in the laboratory at Baltimore by attempts to correlate the records of hearing acuity with the structural conditions found in histologic preparations of the temporal bones.

No conclusions as to the location of the receptors for either single tones or tonal regions can be drawn from the study of cochleæ that are structurally normal at all levels, even though there was impaired hearing. On the other hand, careful study of the cochleæ from many patients with good hearing for all tones, or for the particular tonal region being studied, furnishes valuable information. Such material constitutes a "control group." A thorough knowledge of the lesions that may be present in the ears of people with good hearing is absolutely essential for the proper evaluation of the significance of the lesions found in ears with impaired hearing.

The "control group" that I have used in studying the material of our collection for evidence of low-tone localization is the same as that used by Crowe, Guild and Polvogt in their recently published paper, "Observations on the Pathology of High-tone Deafness" (Bull. Johns Hopkins Hosp., May, 1934), with the addition of those ears from patients with good hearing that have been sectioned during the past year. Briefly, this control group consists of about 200 ears, prepared by the same histologic technic used for those with impaired hearing. In their report the authors give a detailed description of conditions in fifteen of the control ears, selected to illustrate the range of variation in cochlear lesions in the group; and more general statements as to the severity of the middle ear lesions present in some of the other ears with good hearing. Polvogt will soon publish a more complete account of this control group, with particular reference to the lesions of the middle ear that do not interfere with hearing. For the topic today the middle ear lesions are not of importance.

The cochlear observations of Crowe, Guild and Polvogt show that even total atrophy of both nerve and organ of Corti in the ex-

treme basal end of the cochlea is present in some ears without demonstrable functional defects; also that a nerve atrophy averaging as much as 50 per cent in the lower 4 mm. of the basal turn and 20 per cent in the next 3 mm. may be present in ears with good hearing for all tones up to and including 8192 d. v. (see their Fig. 17). These observers also found that the total area of the stria vascularis, as averaged for the whole length of the cochlea, as in some ears with good hearing not more than 75 per cent of its possible maximum area. It is especially important in the consideration of low-tone localization to keep in mind that extensive areas of partial atrophy of the stria vascularis may be present in the apical and middle turns, as well as in the basal turn, in ears with good hearing for all tones; and that this strial atrophy is the most common cochlear lesion found in the apical or the middle turns of ears with impaired hearing.

Cochleæ with total absence of end-organ or of nerve at all levels, whether the condition be due to atrophy (associated with collapse or with ectasia of the scala media), to maldevelopment (as in the albino cat), or to labyrinthitis (acute or with the formation of scar tissue) afford no more evidence as to cochlear localization than do cochleæ that are normal at all levels. But when one or more of the vestibular end organs (maculæ and cristæ) are normal in such ears, evidence is afforded as to whether or not these vestibular end organs have any auditory function. Unfortunately, in ears with the above listed cochlear conditions, the vestibular parts of the inner ear are usually also involved. Therefore the evidence from the material in our collection is not entirely conclusive on this point. Without going into the details of this evidence, I may say that the macula sacculi is the only vestibular end-organ for which an auditory function cannot be definitely excluded. If the macula sacculi of man does have an auditory function, it must be for only extremely loud sounds of a pitch not higher than the middle range of frequencies.

The best evidence available as to tonal localization in the human cochlea is furnished by study of the ears from patients with impaired hearing and with cochlear lesions that do not extend the entire length of the cochlea but yet are more severe than in any of the cochleæ from patients with good hearing. From their correlations of hearing acuity and histologic sections for individual cases with "abrupt" high-tone loss Crowe, Guild and Polvogt have reported that all tones up to and including 1024 d. v. can be well heard by ears with total atrophy of as much as the basal one-third of the total length of the organ of Corti and of the nerve fibers in the osseous spiral lamina to this region (see their figures, especially Nos. 9, 10, 36, 39 and 44). In

Fig. 1. Mid-modiolar section, vertical plane. The spaces of the apical and middle turns contain new bone and fibrous tissue; the organ of Corti and nerve of the upper basal region are atrophic; the lower basal turn has both organ of Corti and nerve present. The dislocation of Reissner's membrane is an artefact of preparation. The greater portion of the trunk of the cochlear nerve, in the internal auditory canal, is atrophic, while the facial nerve and both divisions of the vestibular nerve are normal.

Fig. 2. This section, posterior to the mid-modiolar plane and through the junction of upper basal and lower middle turns, shows the most basalward portion of the obliterative process in the scala tympani. The lower basal turn is practically normal at this level (see Fig. 3.). (The darkly stained mass in the internal meatus is a postmortal blood clot.)

other words, this means that all tones up to and including 1024 d. v. can be well heard when only the apical and middle turns and the upper part of the basal turn are in condition to function. From their evidence, however, it cannot be concluded that the lower basal turn is incapable of receiving some or all of the tones up to 1024 d. v.; *i. e.*, that the low and middle ranges of tones are normally handled only by the apicalward two-thirds of the cochlea.

Our collection contains but one example of a human cochlea with only the lower basal turn present and the rest destroyed. The photomicrographs of two sections from this cochlea (Figs. 1 and 2) show the nature and extent of the important lesions. The osseous and fibrous tissues in the spaces of the apical and middle turns are histologically similar to those found in the obliterative stages of labyrinthitis; and the appearance of the nerve and end-organ in the atrophic part of the upper basal turn is the same as is frequently seen in the lower basal turn of ears with severe impairment of hearing for high tones. The spiral graphic reconstruction (Fig. 3) shows the amount and location of nerve and of organ of Corti present in this cochlea. (For the method of making this spiral graph the reader is referred to the paper by Crowe, Guild and Polvogt *(op. cit.)*. The thresholds of hearing for the octave frequencies from 64 to 8192 d. v. (as determined with a Western Electric Co. 2-A audiometer two and one-half weeks before death from cardiovascular disease with hypertension), are shown by the circles and solid line in Fig. 4. The thresholds for the other ear of this patient, shown by the crosses and broken line in Fig. 4, are about normal for his age (51 years) and the conditions of the examination (in a moderately noisy ward). The ear with good hearing unfortunately was not "masked" during the testing of the poorer ear.

The thresholds obtained for the poor ear for the frequencies of 4096 and 8192 d. v. agree with those that might be expected from the conditions present in the lower basal turn, on the basis of the localization indicated by the high-tone impairment study. The frequency of 64 d. v. was not heard by the poor ear at the maximum intensity produced by the 2-A audiometer; and from 128 to 2048 d. v., inclusive, the thresholds recorded may represent hearing through the head by the good ear; *i. e.*, this part of the audiogram may be a so-called "shadow curve." Had the good ear been "masked" when these tones were perceived (even though greater intensities had been required), the case would constitute good evidence that the lower basal turn can handle these low and middle range tones in addition to the very high tones. The 512 d. v. tuning fork was lateralized to

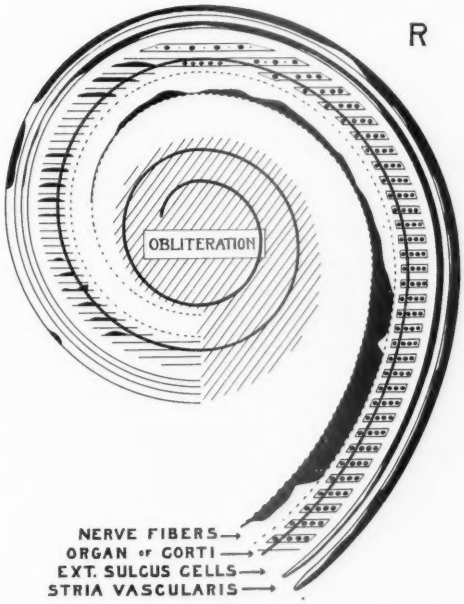

Fig. 3. Graphic reconstruction to show the conditions present in the cochlea illustrated in Figs. 1 and 2.

the left (or good) ear, for which the hearing by air conduction was better than by bone conduction, and the bone conduction time was normal. For the poor ear the fork tests showed bone conduction time as "shortened" and bone conduction as better than air conduction. Since the good ear was not "masked" these observations do not prove that the tuning fork was heard at all by the poor ear. As the examination was performed, the only positive evidence that any frequencies below 4096 d. v. were perceived through this ear is that "spoken voice" (probably loud) was heard by the patient at the same time that a Bárány *lärmapparat* was being sounded in the good ear. Since the understanding of speech requires the perception of frequencies well below 4096 d. v. this observation indicates that the lower basal turn can handle at least part of the speech-range tones. It is of course possible that the hearing for voice was really via the "masked" ear in spite of the use of the lärmapparat.

However, by no argument can it be concluded from this case that low or middle range tones are as well heard via the lower basal turn as they are via the part of the cochlea above this level.

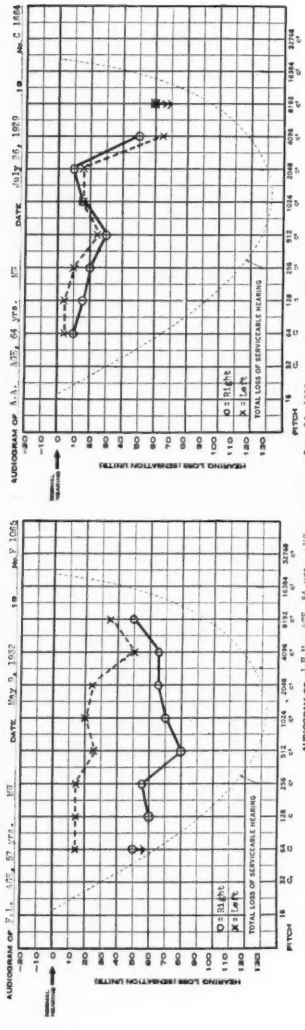

Fig. 4. The audiograms of the patient whose poorer ear is illustrated in Figs. 1, 2 and 3. (See text matter for discussion and for other tests of the hearing.)

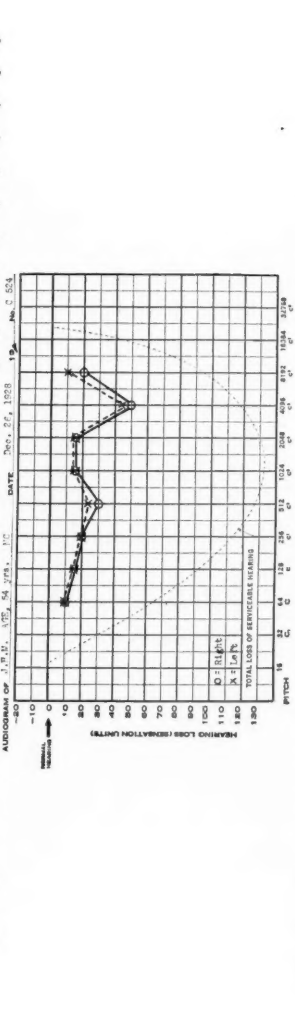

Fig. 5. The audiograms of the patient whose right ear is illustrated in Figs. 7 and 8.

Fig. 6. The audiograms of a second patient with unilateral partial atrophy of nerve to upper middle turn and lower part of apical turn.

The essential structural condition in the case just described is unique: so far as I am aware it is the only human cochlea in any collection of temporal bone sections with an end-organ limited to the region of the lower basal turn. Therefore the functional observations have been presented in more detail than their incomplete nature would otherwise justify. The presentation emphasizes the necessity of adequate "masking" in testing of hearing of all patients with a unilateral impairment: unless this is done it is impossible to make intelligent interpretations, either clinical or physiological, of the data.

The sections of one ear in the laboratory's collection show that an organ of Corti was present in only the apical turn and the upper part of the middle turn; there was total atrophy of end organ and nerve in the lower part of the middle turn and in all of the basal turn. (Photomicrographs and audiogram of this case have been published in the paper by S. J. Crowe, "Anatomic Changes in the Labyrinth Secondary to Cerebellopontile and Brain Stem Tumors," *Arch. Surg.*, Vol. 18, pp. 982-991. See especially Figs 2 to 7.) This is the only ear in our collection in which there is a continuous area of total atrophy extending further apicalward than the lower end of the upper basal turn. Since the opposite ear, which had fairly good hearing, was not "masked," it is possible that the two tones (64 and 128 d. v.) that seemed to be heard on examination with the 2-A audiometer were actually heard by the other ear. In any case, these tones were not heard as well as they are when the atrophy is of the lower basal turn only, and certainly the frequencies from 256 to 8192 d. v. were not heard at the maximum intensities produced by the 2-A audiometer.

In our collection of material the sections of five ears (from four individuals, the condition being bilateral in one) show a circumscribed region of partial atrophy of the nerve supplying the upper part of the middle turn, the lower part of the apical turn, or part of both of these turns (Fig. 7, 8, 9, 10). The organ of Corti is normal in appearance in all five of these ears in the regions with nerve atrophy, except for various degrees of postmortal autolysis and artefacts due to the method of histologic preparation.

The greatest degree of atrophy found is shown in Figs. 7 and 8. These sections are from the right ear of a 64-year-old man who died two years after his hearing was examined. The corresponding regions of the left ear are normal in appearance. Because of the long time interval the relative acuity of hearing by his two ears (Fig. 5) may have changed, even though the sections reveal no evidence that the atrophic process was progressing at the time of his death.

Fig. 7. Mid-modiolar section, vertical plane. There is almost total atrophy of ganglion and nerve to the upper middle turn (see also Fig. 8). The atrophic portion of the cochlear nerve trunk, in the internal meatus, corresponds to this region.

Fig. 8. This section, posterior to the mid-modiolar one of Fig. 7, shows the almost total absence of nerve fibers in the osseous spiral lamina of the region of junction of middle and apical turns.

The right ear of a 54-year-old man, who died only two weeks after his hearing was examined, has a somewhat less extensive area of nerve atrophy than the preceding case. Also, the degree of atrophy is not so extreme as in the preceding case, there being present about one-third of the normal amount of nerve fibers for the region. Although the cochlear lesion is unilateral, the audiograms of the two ears of this patient are practically identical (Fig. 6) and show good hearing except for the frequency of 4096 d. v. There is no indication of a recent change in the cochlear nerve.

The sections of the right ear of a 73-year-old man, whose audiograms are shown in Fig. 11, reveal that there was a partial atrophy of the cochlear nerve supplying about 2 mm. of the organ of Corti near the junction of the middle and the apical turns. Although the lesion is unilateral the acuity of hearing is practically the same for both ears, and is very good for the age. This man died three and one-half months after the hearing was examined.

The cochlear lesions are bilateral in the fourth patient of this group, and the length of the area affected is somewhat greater than in the others. There is a "patchy" distribution of partial and total atrophy of the nerve throughout the entire length of the upper middle turn and into the lower apical turn. On the average the atrophy is of somewhat more severe degree in the left ear (Figs. 9 and 10). The audiograms (Fig. 12) show a slight bilateral impairment of hearing for all low tones, with the left ear slightly poorer for 256 and 512 d. v. The test was regarded by the examiner as not entirely reliable, due to poor concentration by the patient, so that probably his hearing was better than shown by the record. This fact, together with the two and one-half year interval between test and death, make the conclusions that can be drawn from this case alone very indefinite.

But the data for the five ears of this group are in good agreement with each other. While not clear-cut, the evidence from this group of five ears indicates that even a considerable amount of nerve atrophy, when limited to the upper middle and the apical turns, does not have much effect upon the acuity of hearing for low tones: certainly the evidence does not favor the theory that there are sharply localized areas in the human cochlea for the several low tones.

The condition known as scala communis cochleæ is present in seven ears of our collection (both ears of three patients and one ear of another patient). Fig. 15 shows the essential nature of the structural defect that is present in all seven of these cochleæ—absence of

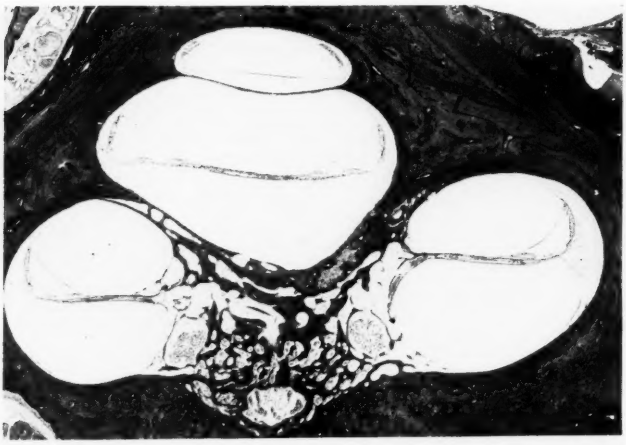

Fig. 9. Section anterior to the mid-modiolar plane, vertical series. This shows the most basalward extent of the 'patchy" atrophy of nerve (in the osseus spiral lamina) supplying the upper half of the middle turn and the lower part of the apical turn. (See Fig. 10.)

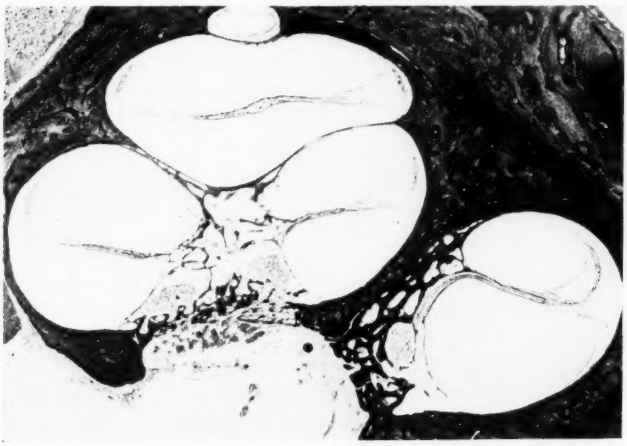

Fig. 10. From the same cochlea as Fig. 9. This section is posterior to the mid-modiolar plane and shows partial atrophy of the nerve to the upper middle and lower apical turns.

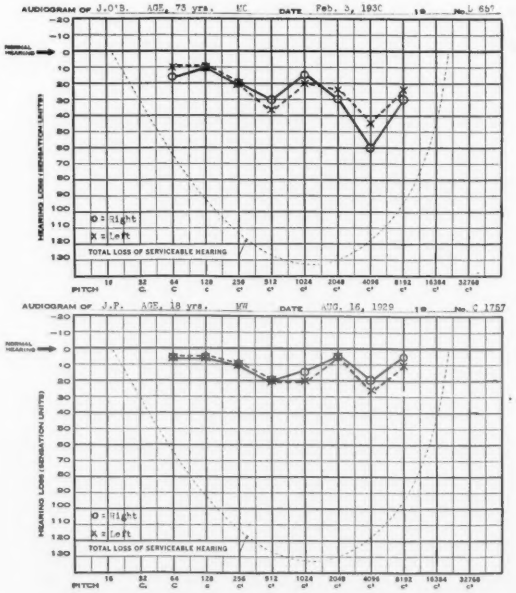
AUDIOGRAM OF J.O'B. AGE, 73 yrs. M/C DATE Feb. 3, 1930 No. L 65?
AUDIOGRAM OF J.F. AGE, 18 yrs. M/F DATE Aug. 16, 1929 No. C 1757
HEARING LOSS (SENSATION UNITS)
NORMAL HEARING
O = Right
X = Left
TOTAL LOSS OF SERVICEABLE HEARING
PITCH

Fig. 11. The audiograms of a third patient with unilateral partial atrophy of nerve supplying junction region of middle and apical turns.

Fig. 13. The audiograms of the patient whose right ear is illustrated in Fig. 15. The condition illustrated is bilateral.

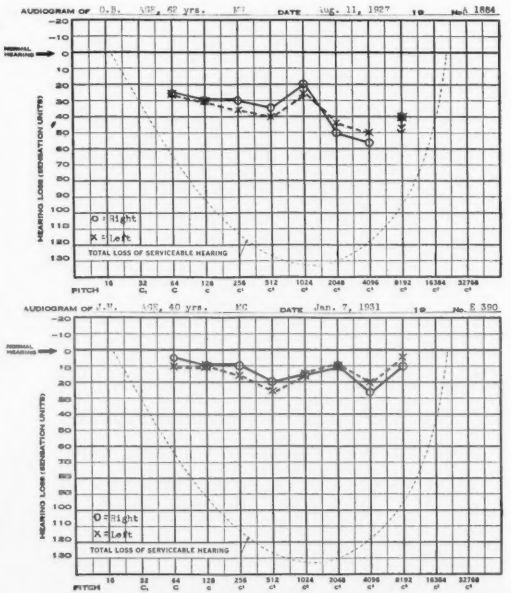
AUDIOGRAM OF D.B. AGE, 62 yrs. M/ DATE Aug. 11, 1927 No. A 1884
AUDIOGRAM OF J.M. AGE, 40 yrs. M/C DATE Jan. 7, 1931 No. E 390
HEARING LOSS (SENSATION UNITS)
NORMAL HEARING
O = Right
X = Left
TOTAL LOSS OF SERVICEABLE HEARING
PITCH

Fig. 12. Audiograms of the patient whose left cochlea is illustrated in Figs. 9 and 10. The lesions were bilateral.

Fig. 14. The audiograms of the patient with a unilateral (left) scala communis cochleae.

a part of the bony septum between the middle and the apical turns. All of these ears had good hearing for the low tones, and most of them for the higher tones also. The patient whose ear is used to illustrate the lesion (Fig. 15) had especially good hearing for the low tones. While the acuity of hearing for low tones was slightly different for the two ears of the patient with a unilateral cochlear defect (Fig. 14), yet both come within the range of normal for the conditions of the examination.

In several other ears of our collection there are blood vessels across the scala tympani of the middle or the apical turn that come up beneath the basilar membrane in the manner shown in Figs. 16 and 17. From the standpoint of our symposium today these cochleæ may be grouped with those having a scala communis cochleæ; both conditions are congenital anomalies or defects that were certainly present at the time the hearing was examined. In case of sharp localization for the reception of low tones either of these conditions should cause impairment of hearing for one or more of the low tones. Careful consideration of all of the evidence provided by this group of cases yields no support to the theory of cochlear localization for low tones.

Besides the above described groups of cases which permit individual correlations to be made between the acuity of hearing and the structural lesions, certain general facts about the material in our laboratory have a bearing upon the question as to whether or not there is cochlear localization in man for the low tones. Our collection contains many examples of lesions of the lower basal turn in ears with impaired hearing for high tones, but very few examples of lesions in the upper turns in ears with poor hearing for low tones. Also, for tones in the lower range of frequencies, it is rarely found on clinical examination that there is a great difference in the thresholds for tones an octave apart; while for the higher tones great differences are frequently observed for tones only a half-octave apart. These general facts indicate that there is some essential difference in the way in which the human ear handles low and high tones.

Partial section of the eighth nerve, intracranially, as done by Dr. Walter Dandy in the operation for the relief of vertigo in Ménière's disease, also provides evidence bearing upon the problem of tonal localization. In those cases in which there is not a distinct plane of demarcation between the vestibular and the cochlear portions of the eighth nerve Dr. Dandy extends the cut into the cochlear part as far as seems necessary to be reasonably certain that all of the fibers of the vestibular division have been severed. Histologic study of the

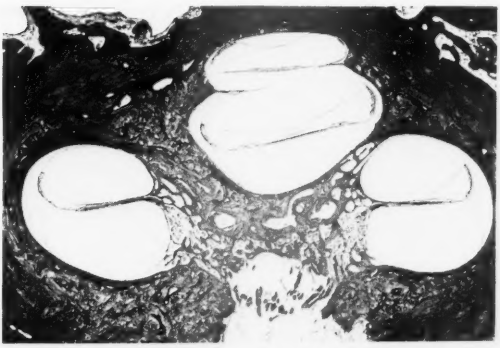

Fig. 15. Section, vertical plane, illustrating the essential nature of the structural defect present in the seven ears with scala communis cochleae. There is partial absence of the septum between middle and apical turns. This permits communication between scala tympani and scala vestibuli at a lower level than the helicotrema. The condition is not an artefact of preparation.

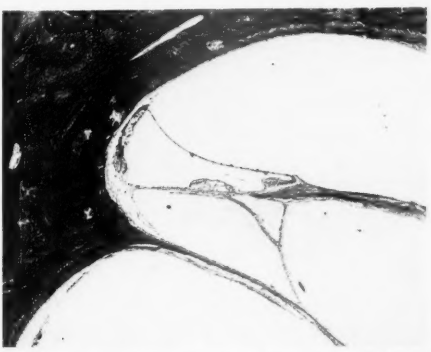

Fig. 16. Shows an anomalous blood vessel arching up beneath the basilar membrane of the lower apical turn. There was good hearing for all low tones.

Fig. 17. Another ear with an anomalous blood vessel crossing the scala tympani of the lower apical turn and in intimate contact with the basilar membrane. Low tones were well heard.

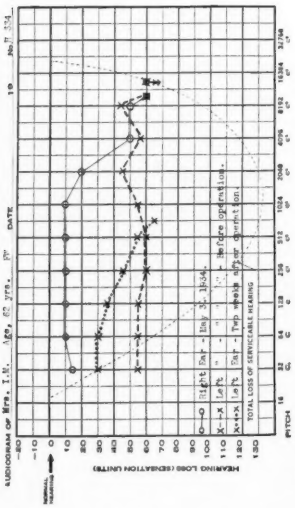

Fig. 19.

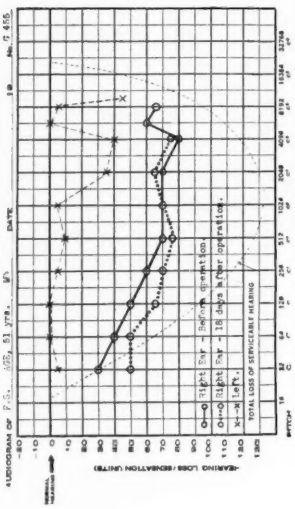

Fig. 18.

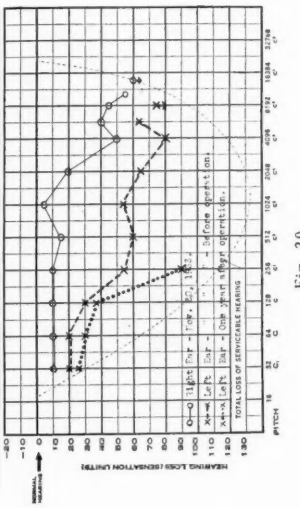

Fig. 20.

temporal bones from these patients would, of course, furnish the best evidence as to the regions of the cochlea affected by this operative procedure, but none have been so studied. (In fact, none of the patients on whom Dr. Dandy has performed this operation have died.) Comparisons of the hearing tests before and after operation, however, do furnish some very interesting physiologic evidence.

The pre-operative examinations of hearing are usually made the day before operation, and the postoperative examinations of hearing usually about one week later. The majority of the patients have not shown any essential differences in hearing as a result of the operation: *i. e.*, the range of tones heard remains the same, and the occasionally observed slight decrease in acuity for some or all tones is within the range assignable to the patient's general condition. For all patients with a postoperative change in the range of the tones heard, it is the upper limit that is reduced—never the lower limit, and never is there a "gap" in the tonal range. Several patients with a preoperative upper limit of 8192, 10321 or 13004 d. v. (the Western Electric Co. 1-A audiometer has been used in the examination of all patients with Ménière's disease) have shown postoperatively a lowering of the upper limit by one or by one and one-half octaves. A typical example is illustrated in Fig. 18. One patient had an upper limit of only 724 d. v. after operation; it was 10321 d. v. before the partial section of the nerve (Fig. 19). In another patient 128 d. v. was the highest frequency definitely heard by the operated ear, with either audiometer or tuning forks (Fig. 20). Dr. Dandy's operative notes for this last patient state that he estimated he had severed about nine-tenths of the cochlear division of the nerve.

The general pattern of arrangement in the cochlear nerve of the fibers from the different turns is such that it is improbable that incisions of various depths into one side of the nerve trunk would divide always the fibers supplying the basal end and never those supplying the apical end of the cochlea. The fibers from the basal turn form, in general, the outer layer of the trunk of the cochlear nerve and those from the apical turn are near the center, so that in making an incision from one side the fibers to the apical region would be severed before all of the fibers to the basal turn are divided. Therefore this evidence is not in favor of the theory of tonal localization in the human cochlea.

Gentlemen, these are the facts, from our observations of human material at Baltimore, that have a bearing upon the topic for the symposium today.

LXXIV.

By C. C. Bunch, Ph. D., and Dorothy Wolff, Ph. D.,

St. Louis.

THE ABSENCE OF THE ORGAN OF CORTI: AN AUDIOMETRIC AND HISTOLOGIC STUDY.*

An awakened interest in the problems of hearing and deafness is evidenced by the number of experimental reports which have recently appeared. Many of these studies have attempted to throw some light on the relationship between the function of hearing and the anatomic structure of the ear. The Wever-Bray technic has opened an avenue of approach to the study of the acoustic nerve and its end organ. Since the proper conditions have not appeared, however, this method has not been used to study the human ear. Histologic studies have been made in certain cases with attempts to apply the results of animal experimentation to human hearing, but it has not been possible to make these experiments clinically practicable. This does not in any way detract from the scientific value of these studies. Other experimenters are following the older method, that of testing the hearing of patients before death and attempting to correlate the histologic observations with the results of the hearing tests. There is no quarrel between those working in these different fields. If the facts of the hearing process are determined, the investigations from all angles of approach must eventually be in agreement.

The difficulties in the way of correlating the results of histologic studies with the hearing tests are great but perhaps not insurmountable. First is the difficulty of obtaining the permit for the postmortem examination of the head. Misplaced sentiment in this country debars many pathologists from observing the various diseased processes in the temporal bone. Routine autopsies including the brain and the temporal bones would be a great help in establishing otology on a firm scientific basis. This procedure means cooperation and a mutual understanding with the morticians.

Second, there is the problem of the perfect removal of the specimens. While this appears to be of minor importance, it often becomes major in securing the desired specimens.

---

*From the Department of Otolaryngology, Oscar Johnson Institute, Washington University Medical School. This study is made possible through the Ball Fund.

A third condition is that the material shall be obtained immediately after the organ ceases to function and before postmortem changes take place. Panse, writing in 1912 in his Pathologische Anatomie des Ohres, states that postmortem degeneration of the organ of Corti begins twelve hours after death. More modern methods of refrigeration might extend this interval.

The preparation of the temporal bone for histologic study is in itself a major problem. The fact that the very delicate end organ is surrounded by dense bone necessitates very exacting technic. Is it possible to assume that the prepared specimen is identical with the living functioning end organ? The best that can be done is to learn the morphologic pictures of the normal and diseased organs, just as pathologists have done in the case of the kidney, lung and other organs of the body. Constant repetition of certain microscopic pictures accompanying certain types of audiograms will eventually give data which will make it possible to correlate the histologic material with the hearing tests.

Another requisite for the success of these correlations is that the hearing tests shall represent the functional possibilities of the end organ immediately prior to the time it ceased to function. In other words, the hearing tests shall be made immediately before death while the patient is able to cooperate accurately, an ideal which can only be approximated.

The conditions presented above indicate briefly some of the difficulties facing those engaged in the solution of these problems when working with human material. Their involved nature and the knowledge to be gained should lead to the free exchange of ideas among investigators. The material presented in this study, the technic with which it has been prepared and the possible inferences which may be drawn from the observations have received more comment and criticism from our own group of workers than can possibly be secured in the brief time allotted for its consideration here. The relevancy of the material to the subject of this symposium may not appear in the subject of this paper, but before the answer to the question of the location of specific receptors for low tones in the cochlea can be secured, the function of the organ of Corti itself must be explained.

In a series of eighteen cases with records of audiometric and other routine clinical hearing tests, six were found in which histologic examination revealed little or no evidence of the presence of the organ of Corti but considerable hearing was indicated by the tests.

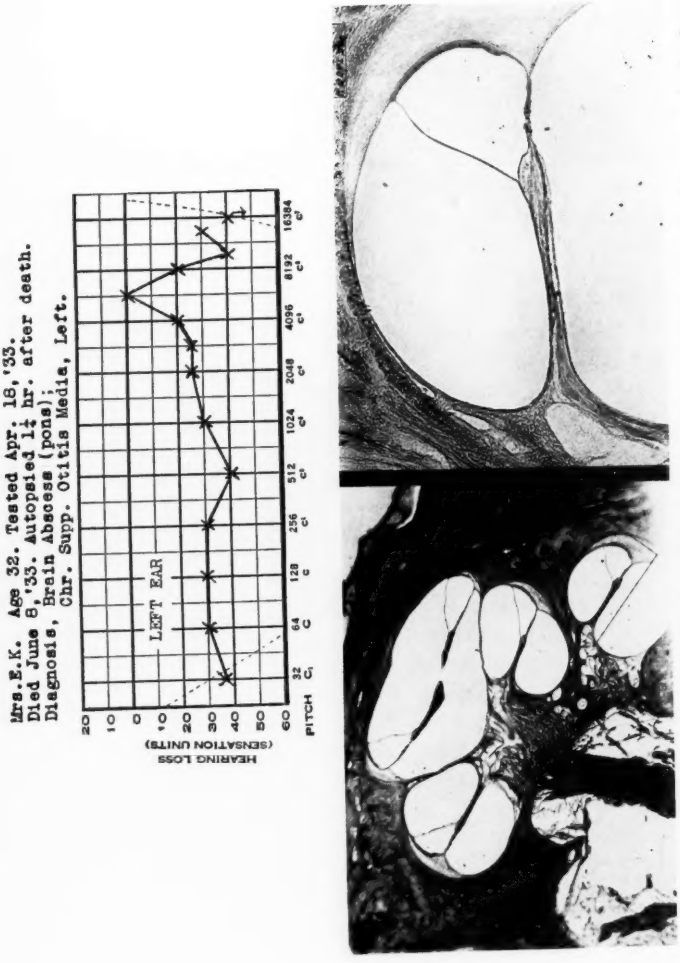
Mrs.E.K. Age 32. Tested Apr. 18, '33.
Died June 8, '33. Autopsied 1¼ hr. after death.
Diagnosis, Brain Abscess (pons);
Chr. Supp. Otitis Media, Left.
LEFT EAR
HEARING LOSS
(SENSATION UNITS)
PITCH
C1 C c c1 c2 c3 c4 c5 c6 c7
32 64 128 256 512 1024 2048 4096 8192 16384

Fig. 1 The audiogram shows some loss in acuity for all tones. Organ of Corti is almost completely degenerated in every turn. The autolysed residuum is apparent in the detailed view of the basal turn.

This condition was bilateral in two cases, unilateral in three and in the sixth, only the right temporal bone was obtained. Three of these cases are presented.

Fig. 1 shows the audiogram and histologic sections of the left ear (No. 5289) of a pregnant white woman, 32 years of age. She entered the hospital after an illness of three weeks. There was first a left facial paralysis, unaccompanied by pain or ear trouble. Three days after the onset of the paralysis, bleeding from the left ear occurred. The drum membrane was incised. The ear continued to discharge. At intervals she suffered from dizziness, nausea and vomiting. Four days after the onset, her left eye became inflamed and the vision was greatly reduced.

Death was due to an abscess in the pons. The autopsy was performed one and one-fourth hours postmortem. The hearing tests were made fifty-one days prior. At the time of the tests there was profuse purulent discharge from the left ear. The Weber test was lateralized to the left; the Rinne was negative in this ear and bone conduction was slightly decreased. The monochord was heard to 15,000 d. v. by both air conduction and bone conduction. She could hear unforced spoken words at eight inches and unforced whisper at three inches. A left cerebellar exposure was done two days after these tests were made but the abscess was not found. A premature child was delivered forty-nine days later. She remained in the hospital until her death, which occurred two days after the birth of the child. No change in auditory acuity was noted.

In Fig. 1, the audiogram is shown with two microphotographs of the cochlea. The low-power view of the mid-modiolar section shows a normal amount of nerve stem in the internal auditory meatus, a good supply of ganglion cells for the various turns and a normal supply of efferent fibers. In this low power the absence of a normal organ of Corti is easily noted. There is a slight liquefaction of ganglion cells in the upper basal turn. The high-power detailed view of the basal turn shows a clump of cells, which in no way resembles the normal organ of Corti, lying on the basilar membrane. Reissner's membrane is intact throughout. The tectorium is agglutinated to the remnant of the organ of Corti. The stria, particularly in the basal turn, is normal, and a normal vessel is seen in the vas prominens.

The audiogram for this ear shows that all tones except 16,384 d. v. were heard, but with considerable decrease in sensitivity. As

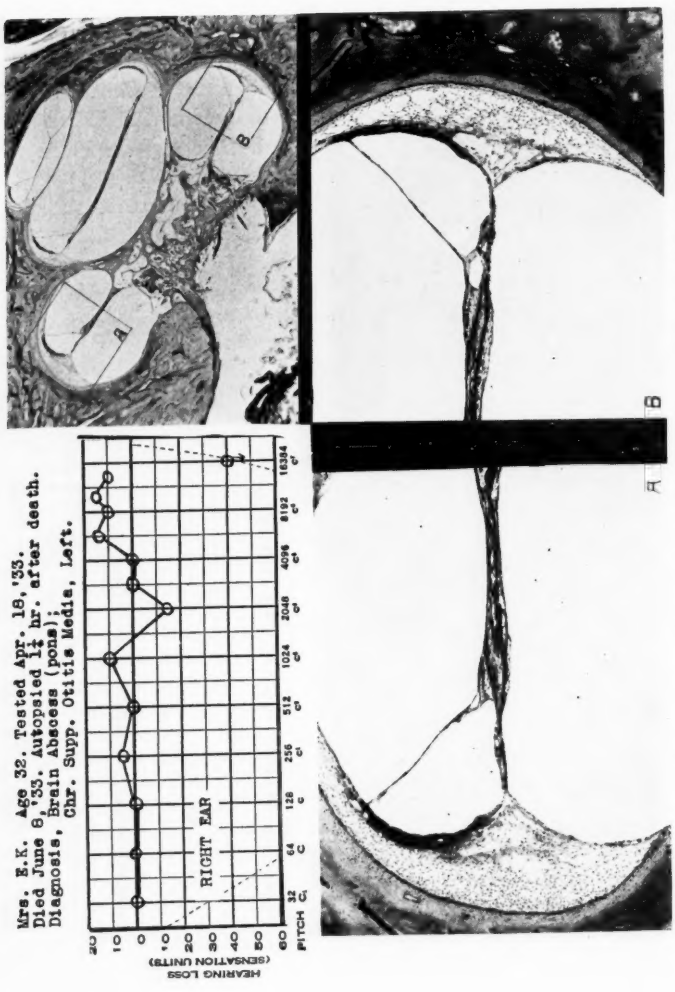

Fig. 2. The essentially normal audiogram of the right ear of the patient whose left is illustrated in Fig. 1. The low-power view is taken superiorly to the mid-modiolar axis, hence fails to catch the organ of Corti in the apical turn. The organ is in good condition throughout.

stated above, she could hear and understand test words spoken in low voice and unforced whisper.

Fig. 2 shows a similar illustration for the right ear of this patient. At the time of the hearing tests the right tympanic membrane was normal. The Rinne was positive and, as noted above, the bone conduction was slightly decreased. The monochord was heard to 19,000 d. v. by air conduction and to 20,000 d. v. by bone conduction.

The low power section on this side is not a perfect midmodiolar cut, therefore the organ of Corti is not visible in the apical coils, but it was present throughout and in excellent condition. The tufts of hairs on the hair cells are visible under the microscope in all turns except the lower basal. Reissner's membrane is also intact on this side but is agglutinated to the limbus and tectorium. Ganglion cells appear to be normal except for a slight reduction in number in the extreme basal turn. Technically, the two ears were carried through the solutions together and were treated exactly alike.

It is admitted in this case that much could have happened in fifty-one days to cause the disappearance of the organ of Corti. There was an active suppurative otitis media in the left, and since the hearing was normal on the opposite side the deafness in this ear might have become more profound without it being noted either by the patient or those in charge.

Fig. 3 shows the audiogram and photomicrographs of the left cochlea (No. 5352) of a 45-year-old colored man. The diagnosis was carcinoma of the esophagus and the autopsy was performed four and one-half hours after death. The Wassermann and Kahn tests were negative. When examined, his pupils reacted sluggishly to light and the conjunctiva was slightly injected. The hearing tests were made in the soundproof room twenty-eight days before death. The Rinne was positive on each side, the Weber was not lateralized and bone conduction was decreased very slightly for both the tuning fork and the bone conduction receiver of the audiometer. The monochord was heard in each ear to 12,000 d. v. by air conduction and to 14,000 d. v. by bone conduction. The drum membranes were of normal luster but appeared slightly opaque and retracted. The audiogram for the left ear shows a very slight loss for tones up to 4096 d. v. and a rather severe loss for those of higher pitch.

The absence of the organ of Corti is evident throughout all turns. With the exception of certain areas of liquefaction in the

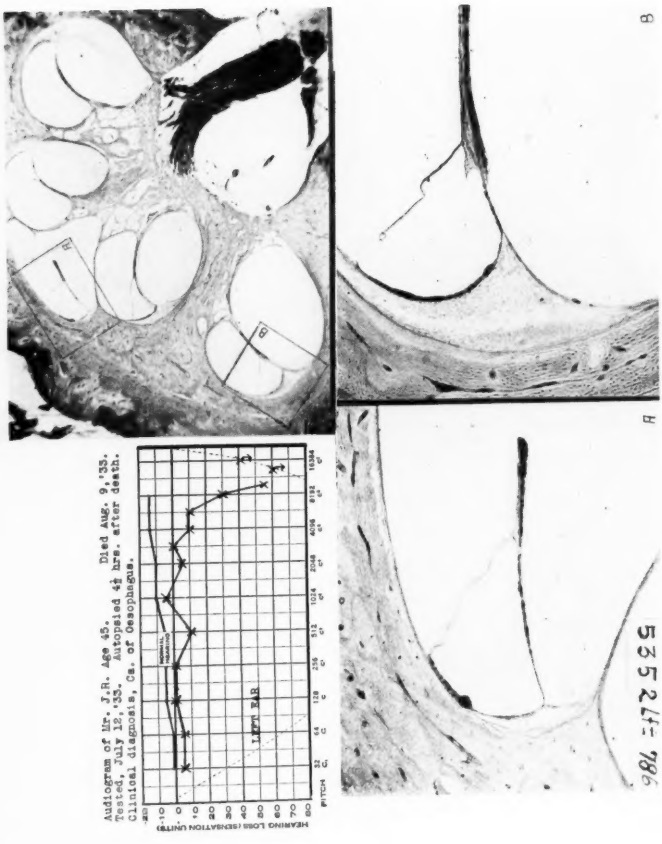

Fig. 3. Essentially normal hearing except for tones of very high pitch. Absence of organ of Corti may be observed in all turns of the cochlea.

lower middle coil, there is a fairly normal supply of ganglion cells and efferent fibers. The high power of the apical turn shows that the stria is pathologic. There is complete atrophy near the basilar membrane with hypertrophy near the very wavy Reissner's membrane. The slight tear in Reissner's membrane shown in the high power of the basal turn suggests that this membrane is undergoing liquefaction. No remnant of the tectorium is present. Apparently it has been completely autolysed.

Fig. 4 shows the audiogram and similar sections of the right ear of this same patient. The audiogram shows slightly greater loss for low tones in this ear than in the left but, as recorded above, the other hearing tests were identical. Histologically, this ear shows essentially the same picture of the organ of Corti as the left. Liquefaction of the ganglion cells in the middle and apical turns is more extensive. The high power view of the basal turn shows a normal vessel in the vas prominens and a fairly normal stria. The tectorium is tilted back and agglutinated with Reissner's membrane which has sunk over a reduced limbus.

A similar condition is illustrated in Figs. 5, 6 and 7, which present the pathologic changes of the third case (No. 5178). This was a white man, 57 years of age, a dentist by profession. His deafness was of many years' duration. He had been repeatedly examined by several otologists, including some from our own staff, and the conclusion was invariably reached that the deafness was of the inner ear or perceptive type. Audiometric tests made by the same examiner under identical conditions on March 23, 1932, and on January 26, 1933, show that the hearing had changed very little in the ten months. He could not hear the c^2 tuning fork when it was held on the vertex for the Weber test. The Rinne was positive on each side, bone conduction was greatly reduced for the tuning fork and for the bone conduction receiver of the audiometer. The Lewis test revealed no fixation of the footplate of the stapes. The monochord was heard only to 8,000 d. v. in the right by air conduction and bone conduction. In the left it was heard to 6,000 d. v. by air conduction and to 5,500 d. v. by bone conduction. He could hear low spoken and whispered words close to each ear with the opposite ear masked.

For several years a disturbing tinnitus had been present but was becoming less noticeable. He had a brother who was hard of hearing in one ear and a sister also was hard of hearing. Four years previously he had had attacks of vertigo, as many as three times daily,

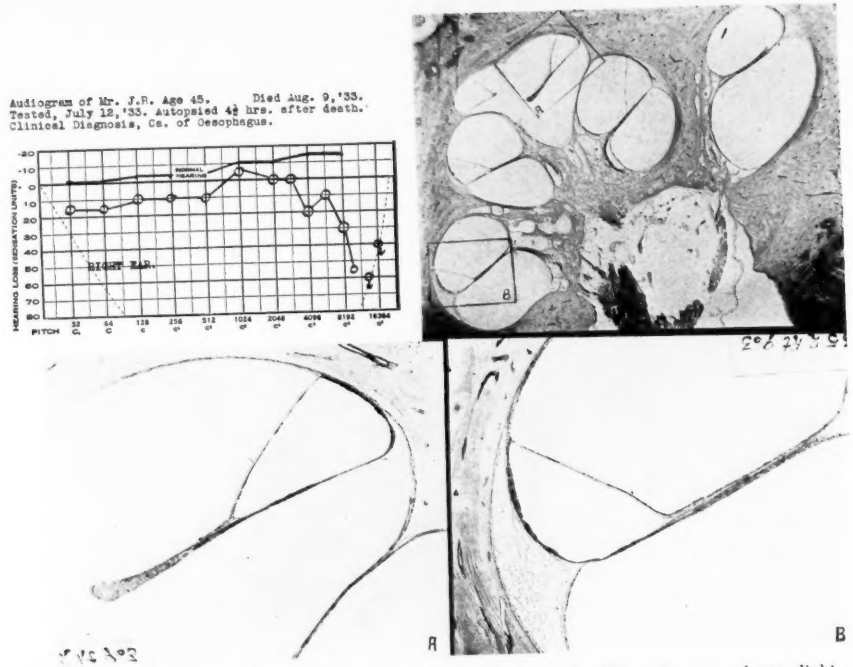

Fig. 4. Right ear of the patient whose left is shown in Fig. 3. The audiometer shows slight loss for low tones and marked loss for high. Almost complete atrophy of the organ of Corti in all turns.

accompanied by nausea and vomiting. These attacks incapacitated him for a year. He had never fallen. Other evidences of intracranial involvement becoming manifest, a right cerebellar operation was performed twelve days after the last audiometer test was done. A tumor about the size of a cherry was found in the right cerebellar lobe. The diagnosis was hemangioblastoma of the right cerebellum. He died eighteen days after the last test. The autopsy was performed eleven and one-half hours after death.

Fig. 5 shows the audiograms for the right ear and photomicrographs of the right cochlea. There is practically a normal supply of neurons and nerve fibers but no evidence of the organ of Corti in any turn. Reissner's membrane is wavy but intact in every turn except the middle. The stria is atrophic and the spiral ligament shows beginning atrophy. The picture is further complicated by the presence of otosclerosis, which is shown in the lower right of the low-power section. This was not suspected from the hearing tests for the clinical indications for its diagnosis were not present. In no section was there any indication that the movements of the stapes were impeded by the otosclerotic process.

Fig. 6 illustrates the audiogram and the conditions found in the left ear of the same patient. The pathologic changes are more severe. Extensive areas of liquefaction of the spiral ganglion are evident throughout. In spite of this, a sizeable bundle of nerve fibers can be seen passing out to a certain region of the basal turn. The main trunk of the cochlear nerve appears normal in mass. Many areas in the modiolus are quite well filled with nerve fibers. Reissner's membrane is intact only in the apical and upper middle coils. In the lower turns it has assumed fantastic positions. In the middle turn it appears as if its two component layers had separated, forming two distinct membranes. Further toward the base, it appears to have liquefied in the middle, leaving a remnant at each point of attachment. In the basal turn only the basal portion of the membrane remains. Panse (ibid.) reports a similar condition in otosclerosis. Although not shown in the photographs, otosclerosis was also present on this side.

Fig. 7 illustrates further the conditions found in this ear. It is quite evident that the block was not mounted properly to get a complete view of the mid-modiolar axis in one section. Reissner's membrane is intact in the apical and upper middle coils. No papilla that resembles the organ of Corti is present.

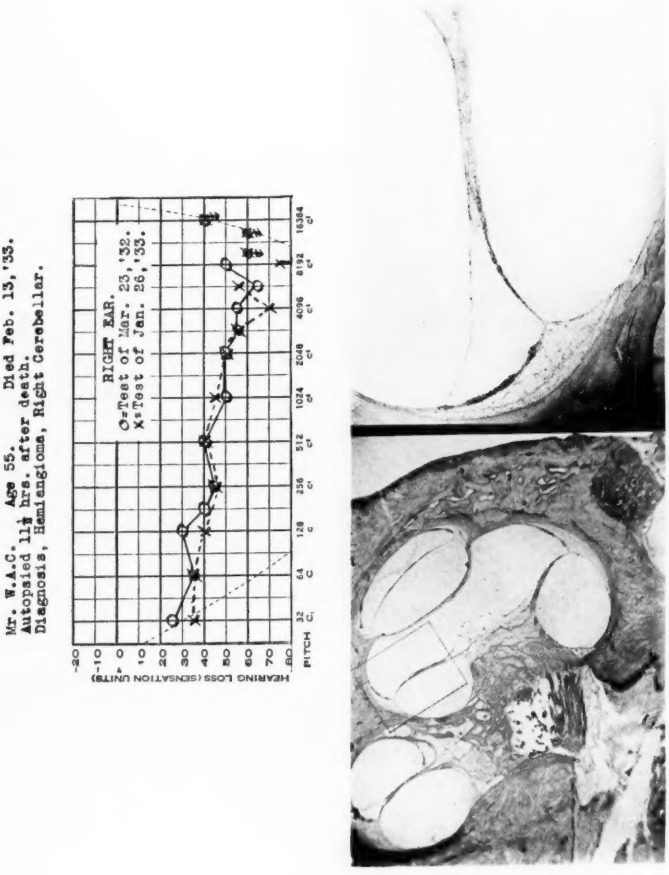

Fig. 5. Two audiograms taken ten months apart show no appreciable change in acuity. Atrophy of organ of Corti is present throughout.

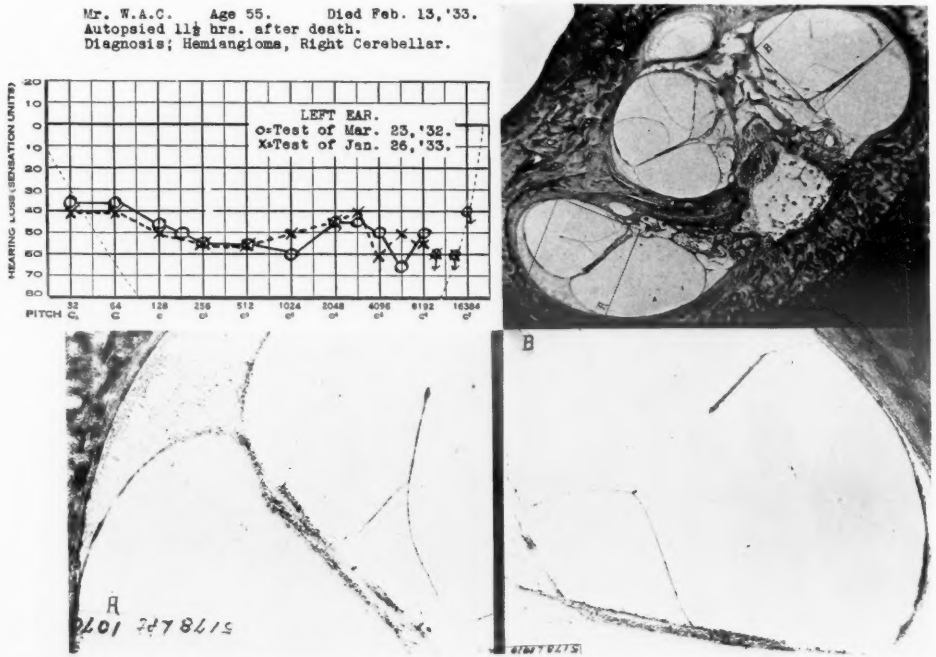

Fig. 6. The left ear of the patient whose right is shown in Fig. 5. The organ of Corti is atrophied. Reissner's membrane has assumed bizarre positions in the basal and lower middle turns.

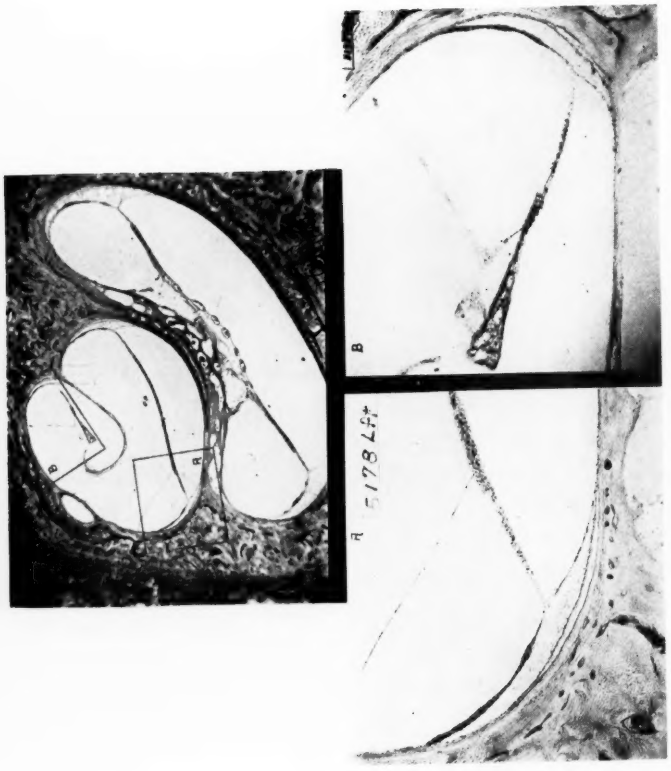

Fig. 7. Another section of the ear shown in Fig. 6. Reissner's membrane is in situ in the apical and upper middle turns.

In these cases autolysis of the organ of Corti does not appear to be due to postmortem degeneration. If it were, there would be evidence of necrotic tissue within the cavity of the cochlear duct. This was not seen in any section. Furthermore, the time elapsed betweeen death and autopsy has in the series of eighteen cases been very short.

Fig. 8 shows the audiograms with high power photomicrographs of the organ of Corti of two cases in which a long interval occurred between death and autopsy. In the one at the top (No. 5039, Left) the intervening time was 15½ hours, the longest in the group. During this time the temperature, according to the Weather Bureau, was not above 74° Fahrenheit. The contour of the organ of Corti is quite normal. The second case (No. 5034, right) was autopsied in September, 14 hours after death. September is often a warm month in St. Louis, but the Weather Bureau reported that the highest temperature during which this body awaited autopsy was 82°. In this section, postmortem degeneration is definitely taking place, but it is the stria rather than the organ of Corti which has broken down. Here, as in the above section, the contour of the end organ is well maintained. One case, not illustrated in these figures, was autopsied two and one-quarter hours after death, during which time the temperature ranged between 93 and 94 degrees. One ear showed a normal well preserved organ of Corti.

Hypertension has been offered as a possible explanation of this pathologic condition of the organ of Corti. Fig. 9 presents the audiogram and photomicrographs of the right ear (No. 5085) of a patient whose death was due to hypertensive heart disease. Twenty-eight days elapsed between the day of the tests and the day of death. The autopsy was performed within two hours. The organ of Corti is of normal height and contour, although the individual component cells are not perfectly normal. The blood pressure of this patient at one time while he was in the hospital was 180/130. Another case of hypertension, not illustrated here, occurs in the group of eighteen tested cases, and it also has an organ of Corti of normal height. It is evidently somewhat accidental if the ravages of hypertension strike the organ of Corti.

In presenting these cases with and without an organ of Corti, the facts are stated only as they have appeared. No conclusions are drawn. No common factor which could have caused the disappearance of the organ of Corti has been found. It is true, however, that all the cases presenting this picture have suffered from a long, wasting illness. To offset this, there is the contradictory evidence that in the

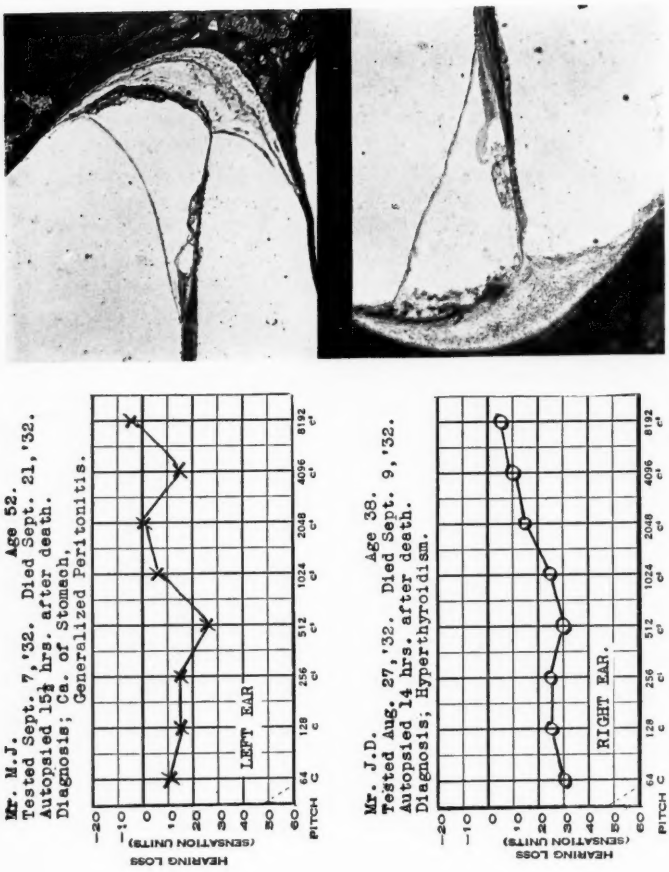

Fig. 8. Audiograms and high-power views of two cases in which the autopsies were done at a relatively long time after death. The organ of Corti is present in both.

series of eighteen tested cases there are others with a similar history which have a practically normal organ of Corti throughout most of its extent. Postmortem degeneration appears to be ruled out because of the promptness with which the autopsies were performed, and this condition of the end organ is not present in two cases in which the longest interval occurred. Agonal changes cannot be entirely eliminated, but it is strange that, if due to this cause, the change should be unilateral in three of the cases.

It has been stated repeatedly that there is nothing new under the sun. Often studies which are thought to reveal new facts are shown to be but verifications of the work of earlier investigators. So it is in this study. Even though the evidence presented appears to contradict the usual textbook pictures and violates the principles of certain theories of hearing which have been proposed, several writers have pointed out this same phenomenon. Denker and Kahler,[1] in a section on the significance of the organ of Corti, writen by K. L. Schaeffer and M. Giesswein, state, on page 490 (authors' translation):

"We know from clinical findings that hearing in humans is possible, although in reduced amount, without the supporting structure of Corti's organ." And again on page 492 (Authors' translation): "From the clinical findings it should again be stressed that Corti's organ with its sensory cells is not absolutely necessary for hearing. It is rather to be viewed as a means for refinement of hearing perception. Zange first stated he had found a few cases accurately investigated shortly before death and later histologically studied, that had proportionately good hearing for whispered voice and tones in spite of bilateral complete destruction of Corti's organ. *He concluded that the finest endings of the hearing nerve are able to take up the sound waves of the basilar membrane directly, without the intervention of Corti's organ.* Wittmaack and his pupil, Runge, have studied similar findings of Corti's organ which was degenerated to a flat surface. "From these investigations it would, therefore, be assumed that sound waves could be taken up immediately from the branches of the hearing nerve itself instead of from apparently destroyed sensory epithelium, so that the ability to hear would not be bound of necessity to the sensory epithelium of Corti's organ."

Panse[2] says (authors' translation): "Bryant thought he could conclude upon the basis of 26 pathologico-anatomical observations of different scientists that the changed parts of the cochlea are not harmonized with different tones, but all are perceived without distinction, the differentiation lying more centrally.

"Matte mentions two preparations from the ear clinics of Jena which show hearing defects. These cases were tested with the continuous tone series. The material was stained with Weigert's and a hearing defect was shown in the corresponding region of the nerve picture.

"I have worked up the existing findings of temporal bones with hearing tests for the International Congress at Ofen-Pest. Bewildering are the findings of

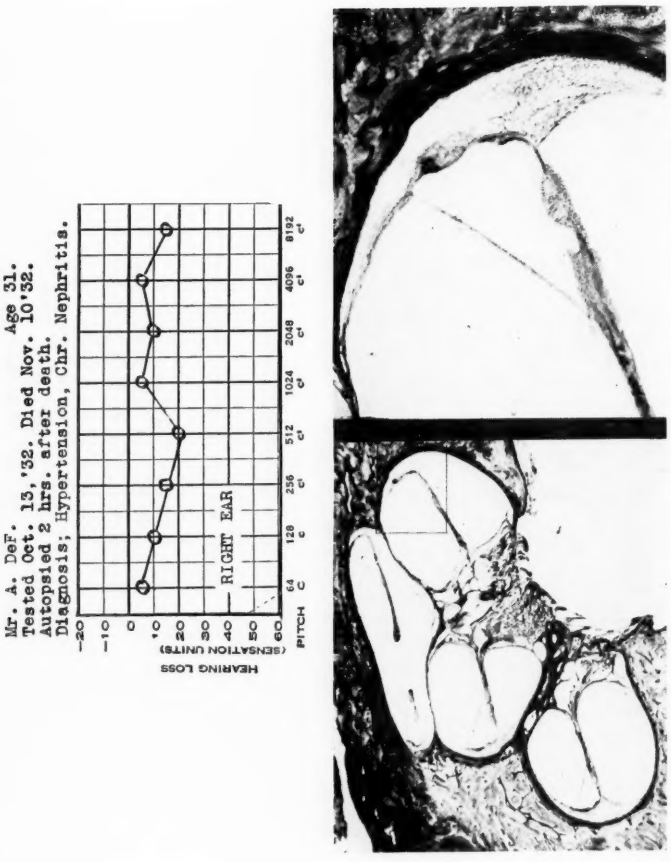

Fig. 9. Audiogram and illustrations of the condition of the organ of Corti in a case of hypertensive heart disease.

Manasse, Panse, and Siebenmann of hearing remnants in complete degeneration of the organ of Corti, then degeneration of the basal ganglion cells in the cochlea in loss for high tones."

Panse illustrates, on page 136, a cochlea with complete atrophy of Corti's organ after a shot had been fired into the ear. The section shows, as he points out, a reduction of ganglion cells in the basal turn, but middle and upper turns appear to have normal ganglion cells. On page 99 he illustrates a specimen with congenital syphilis with the absence of the organ of Corti similar to those presented in this study. Syphilis was not found in any of the three cases illustrated in this report. Serology was positive, however, in three other cases which present these same findings but which have not been included in this report.

Gradenigo, in the sixth chapter of Schwarze's Handbuch der Ohrenheilkunde, Vol. II,[3] reports a case of a 75-year-old man who worked for twenty years in a copper factory and in the course of time became hard of hearing. Fourteen years before his death, when he left the factory, he could still hear if one spoke loudly to him. He became a beggar and met a violent death. At the time of his death he could still hear words which were shouted to him in one ear. Microscopic examination showed that the organ of Corti, tectorium and the nerve in the lamina spiralis were lacking in both ears. Ganglion cells were sparsely scattered.

SUMMARY.

Three cases are presented which shortly before death had varying degrees of auditory sensitivity. The histologic sections of the ears in these cases show degeneration of the organ of Corti throughout its entire extent. An unsuccessful attempt has been made to determine the causative agent. These findings are in agreement with those of certain earlier investigators who found that hearing was possible in the absence of the organ of Corti.

REFERENCES.

1. Denker and Kahler: Die Krankheiten des Gehörorgan. Erster Teil, Sechster Band., Gehörorgan I, Julius Springer, 1926.

2. Panse, Rudolph: Pathologische Anatomie des Ohres, 1912. Vogel, Leipzig, page 132.

3. Schwarze: Handbuch der Ohrenheilkunde, Vol II, Vogel. Leipzig., 1893.

III. DISCUSSION FROM THE POINT OF VIEW OF ANIMAL EXPERIMENTATION.

LXXV.

By E. G. Wever, Ph. D., C. W. Bray, Ph. D., and
G. P. Horton, Ph. D.,
Princeton, N. J., and Seattle, Wash.

In two previous papers, Horton† has reported the results of a series of experiments on stimulation deafness in guinea pigs. In these experiments three groups of animals were subjected to an intense tone for a considerable number of hours, at the rate of ten hours daily. Group I, containing seven animals, was exposed to a tone of 1000 cycles at an intensity of 125 decibels (db) above the human threshold for eleven days, a total exposure of 110 hours. Group II, containing eight animals, was exposed to 1500 cycles at an intensity of 100 db. for 200 days, a total of 2000 hours. Group III, containing four animals, was exposed to 3000 cycles at an intensity of 100 db. for 125 days, or 1250 hours.

For all these animals the auditory sensitivity was determined by the conditioned response method both before and immediately following the exposure. In a number of cases the tests of sensitivity were repeated at intervals after the exposure period, to ascertain whether there was any recovery from the initial effects of the stimulation.

The tests showed in all three groups an impairment of sensitivity of the order of 10 to 30 db. as a result of the stimulation. This impairment was not restricted to the stimulating frequency, but extended in a somewhat irregular way to all tones for which tests were made, from 64 to 8192 cycles. No recovery from this initial impairment was indicated by tests as late as 298 days after the exposure period.

In the present experiment, five of the animals used in the above series were examined by the electrical method. The electrical effects produced in the cochlea during stimulation by sound were led off from the round window through a cotton-wick electrode to an am-

*From the Princeton Psychological Laboratory.

†Horton, G. P.: The Effect of Intense and Prolonged Acoustical Stimulation on the Auditory Sensitivity of Guine Pigs, J. Comp. Psychol., 18, 405-417, 1934; An Experimental Study of Stimulation Deafness in Guinea Pigs, Annals of Otology, Rhinology and Laryngology, 44, 252-259, 1935.

plifier, and recorded by means of a cathode ray oscillograph. A sensitivity curve was obtained for each ear by ascertaining for a great many frequencies the least intensity that would give a detectable deflection on the oscillograph.

Sensitivity curves were also obtained, by the same method, for five control animals. These animals were from the same colony as the above animals and were of similar ages, but had not been subjected to stimulation. The results from the control animals were averaged to provide a base from which to judge the condition of acuity of the experimental animals. This control group type of base is in this instance regarded as more reliable than an animal's own acuity as determined by Horton's previous tests, since a time of about eighteen months elapsed between those tests and the present work, during which the colony was attacked by an epidemic of paratyphoid. Any changes of sensitivity due to age, disease or other conditions not a function of the stimulation would be expected to affect the controls as well as the experimental animals.

The results of the present examination of the five experimental animals are described below and are illustrated in Figs. 1 to 4. In the figures, the sensitivity of these animals is shown in decibels above or below a zero line which represents the average of the control group. The tests were made at 19 frequencies extending from 130 to 8000 cycles. The animals are here given the same numbers as in Horton's previous papers, and the reader is referred to these papers for the details of the earlier, conditioned response tests.

Animal 37.—The previous tests showed that this animal, as a result of the stimulation with 1000 cycles at 125 db. for 110 hours, suffered a slight loss of sensitivity to tones of the middle range, and a complete loss to tones above 2048 cycles. The present (electrical) tests showed a complete absence of effects in both cochleas for all frequencies at the intensities available. No curves, therefore, are given for this animal.

Animal 45.—The previous tests showed that animal 45, as a result of stimulation with 1500 cycles, at 100 db. for 2000 hours, suffered a general loss of sensitivity of the order of 15 to 25 db. The present tests showed a complete absence of effects from the right cochlea. From the left cochlea, effects were observd for high tones only; tones below 1400 were wholly ineffective. At 1400 cycles an intensity of 32 db. greater than normal was required to give a noticeable effect and, as Fig. 1 shows, for higher frequencies the curve of sensitivity rises fairly regularly until at 7000 cycles it is but slightly below the normal line.

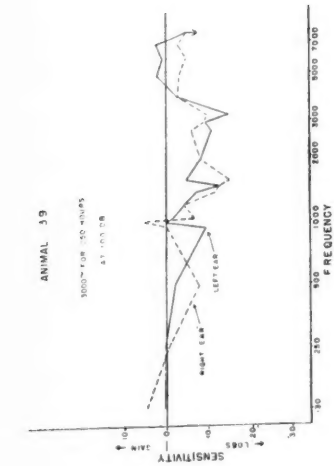

Fig. 2.

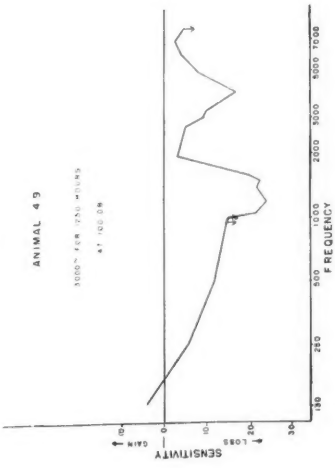

Fig. 4.

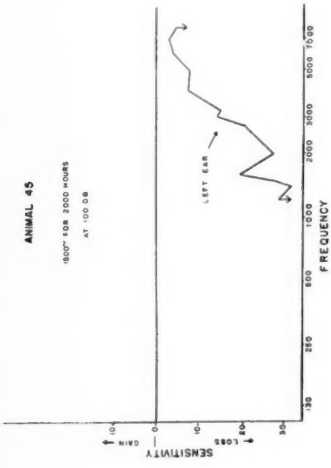

Fig. 1.

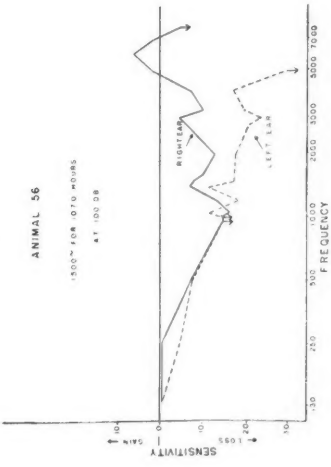

Fig. 3.

Animal 56.—The previous tests showed that this animal, after exposure for 1070 hours to 1500 cycles at 100 db., suffered a loss of high-tone sensitivity of the order of 20 to 30 db. In the present tests, as shown in Fig. 2, sensitivity in both cochleas was about normal for the lowest frequencies, and dropped rapidly to 1000 cycles. For the left cochlea, the drop continued until at 5000 cycles no effects could be obtained. For the right cochlea, however, the trend of sensitivity was upward from 1000 cycles, until for the higher tones it fluctuated about the normal line. Considering the fact that in the conditioned response tests the sensitivity obtained was chiefly a function of the better ear, the results of the present tests agree well with those secured by Horton.

Animal 39.—After exposure for 1250 hours to 3000 cycles at 100 db., this animal was found to suffer a moderate drop in sensitivity for most tones. The cochlear tests likewise showed a sensitivity slightly below normal for most frequencies, as shown in Fig. 3.

Animal 49.—The previous tests showed that, after exposure for 1250 hours to 3000 cycles at 100 db., this animal remained about normal for low frequencies, and suffered only a slight decrease of sensitivity to high frequencies. The cochlear tests showed no responses whatever from the left ear. In the right cochlea, as shown in Fig. 4, sensitivity was about normal for the lowest tones, but dropped to 20 db. or more below normal toward 1500 cycles, from which region there was a generally upward trend until at the highest frequencies sensitivity was but slightly below normal.

The above results, when summarized, show a considerable deficiency of hearing in the experimental animals as compared with the control group. Every one of the ten cochleas studied was below normal in sensitivity. Four of these failed to give effects at any frequencies, and a fifth was wholly irresponsive to low tones. In two of the animals the results correspond fairly closely with those obtained from the conditioned response tests, and indicate, therefore, that there was no significant change of sensitivity during the period intervening between the present and former experiments. In the other three animals, however, there are significant differences, which suggest that there has been further loss of hearing. This loss may be accounted for either as due to a continuation of degenerative changes consequent to the stimulation, or as due to diseases of the auditory mechanism to which the stimulation rendered the animals especially liable.

The results of this investigation agree with the conditioned response studies previously reported in indicating a general rather than a specific impairment of hearing as a result of stimulation with a single frequency of sound at great intensity. For the problem of localization in the cochlea, this seems to indicate no important degree of specificity for such tones. It is probable that when a tone attains an intensity of 100 db. or more, it involves practically the entire extent of the basilar membrane and allied structures. It should be added, however, that these results do not indicate a correspondingly great spread for tones of more moderate intensity. The degree of localization in the cochlea is probably a complex function of intensity and frequency, the precise nature of which further experiments, using various methods, may be expected to reveal.

The temporal bones of the animals used in this study are in course of preparation for microscopic examination, the results of which will be reported later.

LXXVI.

By H. Davis, M. D., M. H. Lurie, M. D., and S. S. Stevens, M. D.,*

Boston.

The electrical potentials generated in the cochleas of guinea pigs were picked up by electrodes placed on the round window and the neck, and were studied by means of a cathode ray oscillograph. We believe that these potentials are a good indicator of the ability of the animal to hear, because (1) they are absent in deaf animals, (2) they have thresholds which correspond closely to the threshold of hearing in humans and also in guinea pigs tested by the method of conditioned reflexes, and (3) equal potentials are produced at different frequencies by the same strengths of stimulation as yield tones judged equal in loudness by human observers.

Electrical audiograms were taken before and after drilling through the cochlear wall and damaging the organ of Corti at various levels. The exact location and extent of each lesion was determined by subsequent microscopic study of serial sections of the cochleas and these were correlated with the losses in hearing revealed by the audiograms. The losses in most cases were not greater than 20 to 30 db. and sometimes were definitely limited to one or two octaves. Sometimes hearing was depressed for all tones below a certain limit. The best correlations could be obtained between the boundaries of

*From the Departments of Physiology and of Otology and Laryngology, Harvard Medical School.

the lesions and the first deviations from the control in the audiogram. In twenty animals a consistent correlation of this sort was obtained. High tones are localized near the basal end of the cochlea; 2000 c.p.s. is at the middle; and the low tones, to which we directed particular attention, are bunched quite closely toward the helicotrema—more closely than has previously been supposed.

A tone 20 or 30 db. above threshold apparently activates a considerable zone of the organ of Corti, but this fact does not in any way contradict the fundamental localization described above.

A striking feature of these results is the indication that the resonant area for each particular tone is located in the ear of the guinea pig in the same relative position as in the human ear when the human location is determined by graphical integration of the most recent data for differential sensitivity to pitch. The same close grouping of low tones near the helicotrema appears in both cases.

LXXVII.

By Walter Hughson, M. D., Eva Thompson, M. D., and E. G. Witting, M. D.,

Baltimore.

Introduction.

Two general avenues of approach are available in any investigation of this kind. Clinically deaf animals may be studied experimentally, while, on the other hand, animals may have experimental lesions produced upon their cochleæ and the effect of such procedures determined. Experimental lesions may again be divided into two groups. These are lesions produced under strict aseptic surgical technic, the animals allowed to survive and examined at varying intervals of time thereafter, or the simpler and more usual type of experiment in which lesions produced acutely are immediately investigated. Audiograms obtained from these animals, whether clinically deaf or with transmission reduced experimentally, must have adequate histologic control of the extent and type of lesion present and such lesions correlated with the transmission findings.

Such an investigation of cochlear function has been in progress over a period of three years, during which a large number of animals

*From the Otological Research Laboratory and the Surgical Hunterian Laboratory, Johns Hopkins University School of Medicine. Aided by a grant from the Ella Sachs Plotz Foundation for the Advancement of Scientific Investigation.

(111) have been studied by the three methods mentioned above. Cats have been used exclusively. In the great majority of cases the audiograms have been obtained with the Wever and Bray technic—that is, by using a nerve electrode. Where intensity of transmission of any frequency was found to be markedly reduced or absent by the nerve electrode, recourse could always be had to a silver foil electrode on the round window to establish finally whether any particular frequency was not transmitted. The range of frequencies studied has in most instances been the same as in previous reports, from 180 to 8000 d. v., although when there seemed some particular reason for so doing 64 and 128 d. v. were added to the usual range. Frequencies below 64 d. v. have been found to introduce difficulties of control and error in measurement which make them of little value.

A definite standard for analyzing the transmission tests has been established to indicate whether or not any number of frequencies were definitely lost. Impairment in threshold values may be due to a number of causes, particularly in the chronic type of experiment, while complete failure to transmit at the highest intensity of stimulus available from the apparatus used may properly be regarded as a matter of cochlear function. This is especially true when measurements are made by the round window electrode. The safety and accuracy with which intense sound stimuli may be used in pathologic ears has been amply investigated. Under such circumstances overload was not apparent and no fatigue developed, even though the stimulus was continued over a considerable period of time. Therefore no frequency was considered affected unless it was completely absent both by the nerve and the cochlear electrode at the maximum intensity of stimulus available from the sound source. This standard corresponds closely, from the audiometric standpoint, to clinical cases of abrupt high tone loss.

Albino Cats.—Howe and Guild[1] first reported a detailed study of transmission tests in clinically deaf albino cats. These animals failed to transmit either by nerve or cochlear electrode at any intensity of stimulus by air, nor was there any response by bone conduction. Furthermore, if true albinos, the sections invariably showed the typical micropathology of the organ of Corti, Reissner's membrane and a reduction in the number of ganglion cells.

Spontaneous Atrophy.—In the large series of animals examined a few cases of clinically deaf individuals have been found to have spontaneous atrophy of the organ of Corti, nerve and ganglion cells, ranging from almost complete absence to varying degrees of partial

atrophy. Of considerable interest in these cases has been the completely normal structure and position of Reissner's membrane throughout the entire length of the spiral. Where frequencies were lost when leading from the nerve they were also absent when the lead was taken from the round window. A protocol of such an experiment follows.

PROTOCOL 1.

EXPERIMENT NO. 259 B.

May 19, 1933: Cochlear wall scorched at base of drill hole made high up towards apex, right.

Anesthesia: Intratracheal ether. Started 3:05 p. m.; ended 4:05 p. m.

Procedure: Operative field cleaned with iodine and alcohol. The right bulla and middle ear were opened in the usual manner. A hole was drilled partially through the cochlear wall as high up towards the apex as possible, just inside the middle ear. On account of the size of the cat and the thickness of the cochlear wall it was burned slighty longer than usual with the high frequency cautery. The bone was extremely hard and calcified. There was no bleeding. Wound was closed in usual manner. Animal in good condition at end of operation.

June 5, 1933.

Anesthesia: Intratracheal ether. Started 9:45 a. m.; animal sacrificed 11:45 a. m.

Procedure: Animal prepared for test in usual manner, electrodes being placed on both auditory nerves. Ground electrode placed in back of neck. Stationary headrest used. Neither bulla was opened until after control tests had been made.

Results: Practically no transmission present by the nerve electrodes. The left ear was opened and found to be perfectly clear. An electrode was placed in the round window niche but transmission from this electrode was also practically absent. This round window electrode serves as an excellent check on transmission from the nerve. No explanation could be found by gross examination for this lack of transmission, so the animal was injected through the heart with formalin and both ears saved for sectioning.

Autopsy: Both ears seemed perfectly normal except for drill hole in right cochlea which could be plainly seen.

As stated in the protocol, the animal was operated upon the right side. When tested two weeks later transmission on both sides

Fig. 1. Photomicrograph of left cochlea showing complete atrophy of organ of Corti, auditory nerve and ganglion except for small portion of apical region.

was practically absent; a few syllables only of the voice record were detected. When the sections were examined there was found an almost complete atrophy of the organ of Corti, nerve and ganglion. (Fig. 1.) In addition, the auditory nerve itself showed atrophy except for a few fibers extending from the apical region where there was a small amount of normal organ of Corti. Throughout the entire cochlea Reissner's membrane was normal. This animal was not an albino.

The procedure employed to produce acute lesions of the organ of Corti for the past three years has been that already described by Hughson, Crowe and Howe.[2] Bearing in mind the fact that reduction of intralabyrinthine pressure invariably causes a reduction in the intensity of transmission, small drill holes were made in the wall of the cochlea at selected levels from the base to the apex. (Fig. 2.) Except as will be described below, these drill holes were never carried through the cochlear wall. The base of the drill hole was then scorched with a high frequency cautery. There followed in these acute experiments a complete loss of some frequencies and a general lowering in the intensity of all that remained as compared with the control measurements. Twenty-nine experiments of this type were carried out, and it soon became apparent that the acute reaction to scorching had a more general effect on transmission than occurred in

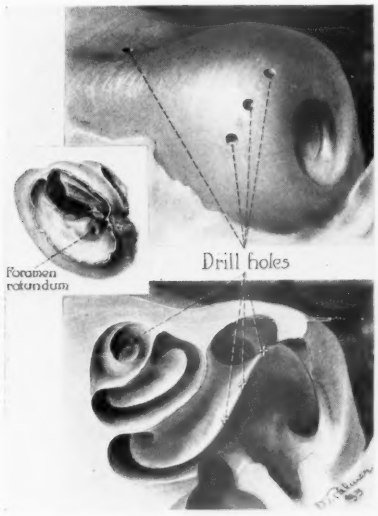

Fig. 2. Illustration showing position of drill holes made partially through wall of cochlea.

the chronic experiments. It was felt that this general lowering was due to a transient coagulation of endolymph and perilymph, while complete absence of transmission resulted from actual localized destruction of the organ of Corti.

In a recent series of experiments drill holes were made through the wall of the cochlea at the apex. Loss of intralabyrinthine fluid following perforation at the apex is slight and takes place slowly. Slight hemorrhage may result if the spiral osseous lamina at the apex is fractured. If such an opening was promptly closed with a plug of silver foil no leakage of any consequence occurred and transmission for all frequencies was affected little if at all. If the opening was not sealed there followed a gradual loss in the intensity transmitted. No specific effect resulting from destruction of the apex itself was observed.

In this general connection must be mentioned a series of experiments in which the procedure described by Hallpike and Rawdon-Smith[3] was repeated exactly. These investigators made drill holes in the cochlear wall, as described above, filled the holes with drops of mercury and placed their electrode so as to make contact with the mercury. They found that with an electrode near the apex the lower frequencies were transmitted with greater intensity than at the base

and vice versa. It has been impossible to confirm this observation except, as has been repeatedly shown, that any electrode near the base or at the round window transmits all frequencies from 1000 to 8000 d. v. at high intensities. All frequencies are transmitted with lowered intensity the further away the electrode is placed from the round window. If the drill hole is made completely through the wall of the apex and the electrode inserted therein, thus preventing any considerable escape of fluid, the intensities approach very closely those obtained at the round window.

Chronic Experiments.—The difficulty experienced in controlling all the factors resulting from acute damage of the cochlea is much more marked than in experiments performed on other structures of the ear. Therefore, the preliminary procedure of drilling and scorching was carried out under strict aseptic technic and the animals kept alive for varying intervals of time before being tested. The destruction is localized in direct proportion to the vigor with which the particular area is scorched. After a period of ten days there develops, in addition to the destroyed organ of Corti, atrophy of the nerve itself. In addition the frequencies lost are those beginning with the highest of the scale and gradually extending downward. Cochleæ with all degrees of damage in every available position have been studied and the transmission tests obtained controlled by histologic sections. Experiment No. 194 B is an example of slight apical damage with practically normal transmission. The protocol follows:

PROTOCOL 2.†

EXPERIMENT NO. 194 B.

March 13, 1933: Cochlea scorched at base of drill hole made partially through cochlear wall with No. 80 drill. Hole made at apex inside middle ear, right.

Anesthesia: Intratracheal ether. Started 3:30 p. m.; ended 4:30 p. m.

†As a basis of comparison the various frequencies are impressed on the cat's ear at an intensity ranging from 75 to 90 decibels above average human threshold. This intensity is referred to as "normal" and is 15 decibels below the maximum which can be obtained from the continuous pitch range audiometer for 180, 250, 500 and 4000 d.v. while for 1000 and 2000 d.v., 25 decibels below maximum is used. "Normal" intensity is used unless otherwise specified in the protocol. The figures beneath the different frequencies represent decibels of attenuation necessary to balance the comparison intensity with the intensity of tone transmitted through the cat's ear.

Procedure: Operative field cleaned with Scott's solution. The right bulla and middle ear were opened in the usual manner. A hole was drilled partially through the cochlear wall at the apex, just inside the septum, and the base of this hole scorched with the high frequency cautery. There was no bleeding. Wound was closed in usual manner. Animal in good condition at end of operation.

March 20, 1933.

Anesthesia: Intratracheal ether. Started 9:50 a. m.; animal sacrificed 2:30 p. m.

Procedure: Animal prepared for test in usual manner, electrodes being placed on both auditory nerves. Ground electrode placed in back of neck. Stationary headrest used. Neither bulla was opened.

Results: Right side slightly better than left side. Detailed results are as follows:

AIR CONDUCTION.

RIGHT EAR.

Procedure	180	250	500	1000	2000	4000	8000
Voice record, maximum intensity, 70 db.							
Control, normal intensity		38	34	39	42	42	

LEFT EAR.

Voice record, maximum intensity, 77 db.							
Control, normal intensity	48	40	39	46	50		

After these control tests had been made and it was found that there was no pick-up present all the intermediate tones on the right side between 180 and 8000 were tested at an intensity 15 decibels below maximum. The continuous pitch range audiometer made available through the courtesy of Dr. Harvey Fletcher of the Bell Telephone Laboratories, permits testing for all tenths of octaves.

Frequency	Decibels of atten.	Frequency	Decibels of atten.	Frequency	Decibels of atten.	Frequency	Decibels of atten.
180	60	470	40	1230	33	3230	40
190	57	500	36	1320	35	3500	40
200	56	540	35	1400	34	3710	43
216	54	580	36	1500	33	4000	42
232	51	620	35	1620	35	4300	41
250	47	660	34	1750	34	4600	42
266	46	710	33	1880	33	5000	47
285	44	760	35	2000	39	5350	49
305	44	820	36	2140	37	5700	48
330	44	870	34	2300	38	6100	47
350	46	930	36	2420	37	6600	50
380	49	1000	36	2600	38	7000	*
410	59	1080	35	2800	38	7600	
435	45	1150	34	3000	39	8000	

*Too faint to balance.

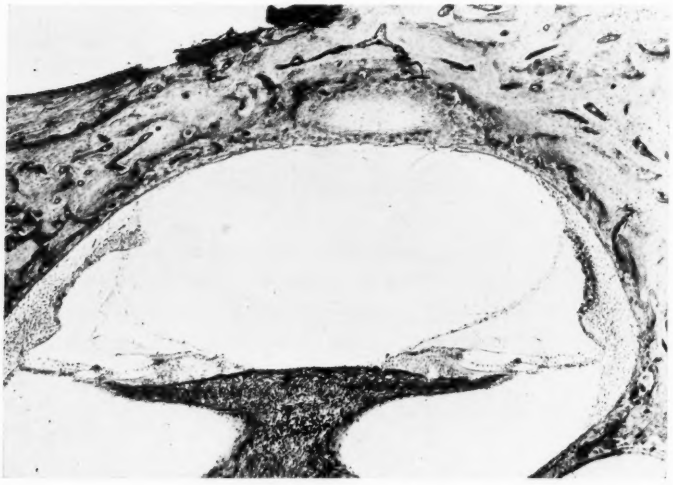

Fig. 3. Photomicrograph of upper middle portion of cochlea showing scorched area. Note damaged outer hair cells and coagulated endolymph in cochlear duct.

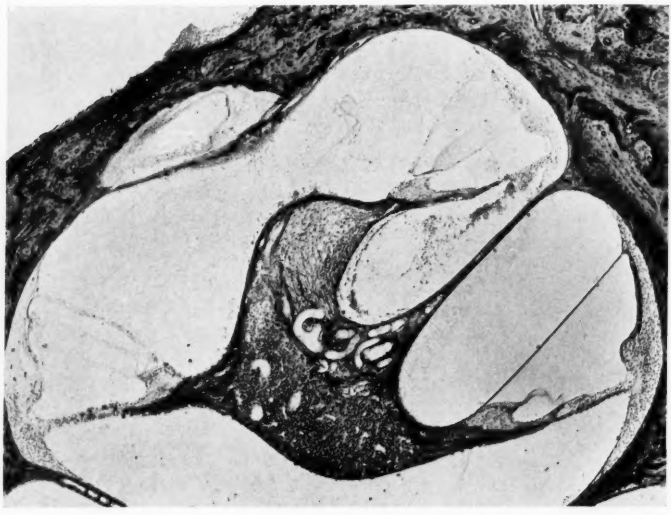

Fig. 4. Scorched area of cochlear wall. Note damaged organ of Corti and beginning atrophy of auditory nerve.

Autopsy: There was a small amount of blood stained serum in the middle ear. Although the drill hole could be seen, no very marked evidence of scorching was present.

Note on sections: In the region adjacent to the scorched cochlear wall the outer hair cells have been damaged and coagulated endolymph is present in the cochlear duct. (Fig. 3.)

In another experiment, No. 765, more severe damage was done to the organ of Corti, but the cochlear wall was still kept intact. (Fig. 4.) In this animal the organ of Corti at the apex was destroyed as well as at the upper middle on the lateral surface. In the interval of six days between operation and testing, nerve atrophy had already developed extending down the nerve trunk itself. The protocol of this experiment follows:

PROTOCOL 3.

EXPERIMENT NO. 765.

May 3, 1934: Cochlea scorched at apex, inside septum, right.

Anesthesia: Intratracheal ether. Started 2:25 p. m.; ended 3:35 p. m.

Procedure: Operative field cleaned with iodine and alcohol. The right bulla was opened in the usual manner and the septum removed. Using the side of the dental burr, a hole was drilled partially through the cochlear wall at a spot in line with the anterior border of the tensor tympani muscle. With a curved needle the base of this hole was scorched vigorously with the high frequency cautery. There was no bleeding. Wound was closed in usual manner. Animal in good condition at end of operation.

May 9, 1934: Animal developed neck infection.

Anesthesia: Intratracheal ether. Started 9:45 a. m.; animal sacrificed 11:45 a. m.

Procedure: Animal prepared for test in usual manner, electrodes being placed on both auditory nerves. Ground electrode placed in back of neck. Neither bulla opened until after control tests had been made. Metal headrest and copper shield used.

Results: Transmission slightly better on left than on right side. Detailed results are as follows:

AIR CONDUCTION.

RIGHT EAR (Operated).

Procedure	Intensity	180	250	500	1000	2000	4000	8000	
Voice record 70 db.									
Control	Normal	....	34	30	30	37	37	70	
Pickup test	"	....	....	....	....	....	....	....	
Threshold test	-30	....	....	60	....	....	....	....	
	-20	....	....	46	45	....	....	....	
	-10	....	44	35	36	44	64	....	
	Normal	....	32	30	30	40	47	69	
	10	24	24	20	20	20	33	60	
15 (1000, 2000 at 20)		23	20	20	20	19	33	....	
	Maximum	20	23	20	20	20	32	....	
Pickup test	"	....	....	....	....	....	....	....	
Bulla opened, cleaned out, cochlear electrode over round window	64 128								10,000
Potentiometer at 8	....		30	29	31	36	34	70	....
Pickup test	....		....	....	....	....	*	*	....
Cochlear electrode, without potentiometer	30 27		20	17	17	14	14	40	....
Pickup test	....		....	....	....	....	*	....	....
Nerve electrode, C.E. still over r.w.		....	26	25	25	28	27	56	
Nerve electrode, cochlear electrode removed		....	30	27	24	24	25	57	

LEFT EAR.

Voice record 50 db.									
Control	Normal	24	29	29	34	36	47	70	
Threshold test	-30	40	39	33	33	46	63	....	
	-20	31	30	30	33	39	57	....	
	-10	30	29	30	35	39	57	60	
	Normal	28	27	30	34	39	54	69	

*Too faint to balance.

Note that on the right or operated side threshold values were impaired, whereas at normal attenuation little difference could be shown between the two sides. Further, using the cochlear electrode, the frequencies 64 and 128 d. v. were transmitted. In this animal insufficient damage was done to the organ of Corti to affect any frequency.

If damage is produced at the apex, even to the extent of perforating the cochlear wall and actually inserting the cautery needle inside the cochlea at this point, the higher frequencies are again lost,

while the lower frequencies are seldom completely lost, though usually lowered in intensity. In one experiment a middle ear infection followed operation, and though the entire apex was filled with pus in addition to destruction of the organ of Corti, the lower frequencies were still transmitted. Though an obvious result of this procedure, attention should be called to the fact that after such scorching at the apex the helicotrema is of necessity obliterated.

PROTOCOL 4.

EXPERIMENT NO. 770.

May 10, 1934: Cochlea scorched at base of drill hole made just inside septum at apex, right.

Anesthesia: Intratracheal ether. Started 2:25 p. m.; ended 3:30 p. m.

Procedure: Operative field cleaned with iodine and alcohol. The right bulla and middle ear were opened in the usual manner. Using the side of the dental burr a hole was drilled partially through the cochlear wall at a spot in line with the anterior border of the tensor tympani muscle. The base of this hole was then scorched vigorously with the high frequency cautery. Apparently the needle penetrated the apex of the cochlea. There was practically no bleeding, however, Wound was closed in usual manner; animal in good condition at end of operation.

May 12, 1934: No signs of nystagmus or vertigo.

May 16, 1934: Slight neck infection.

May 22, 1934.

Anesthesia: Intratracheal ether. Started 10 a. m.; animal sacrificed 12:00 m.

Procedure: Animal prepared for test in usual manner, electrodes being placed on both auditory nerves. Ground electrode placed in back of neck. Metal headrest and copper shield used. Neither bulla opened until after control tests had been made. Tests made with silver foil electrode in round window niche.

After an interval of two weeks tests were made and, as the figures indicate, all frequencies from 180 to 2000 d. v. were obtained by the nerve electrode, and with the cochlear electrode 128 to 4000 d. v. were transmitted. Sections showed complete destruction of the apex with total nerve atrophy in this region. The scorching had apparently sealed off the apex of the cochlea because the infection did not extend below the upper middle turn. At no time did the animal exhibit nys-

tagmus or vertigo. The first normal organ of Corti was found in the upper basal turn.

Results: Transmission very poor on right, slightly below average on left. Detailed results are as follows:

AIR CONDUCTION.

RIGHT EAR (Operated).

Procedure	Intensity	180	250	500	1000	2000	4000	8000
Voice record—								
Control	Normal	....	....	37	42	63	....	....
Pickup test	"	....	....	....	....	....	....	....
	10	....	40	31	39	70	....	....
	15 (1000, 2000 at 20)	36	36	32	30	60	....	....
	Maximum	34	40	33	30	60	....	....
Bulla opened, silver foil electrode over round window niche	64	128						
Potentiometer at 8	....	....	....	....	....	....	*	....	....
Without potentiometer	....	39		45	46	61	67	69	....
Pickup test	....	....		....	....	....	....	....	....
Maximum intensity	....	34		38	47				
Maximum intensity pickup test	....	....		....	67				

LEFT EAR.

Voice record 39 db.								
Control	Normal	30	40	24	29	38	54	52

*Too faint to balance.

Detonation Experiments.—In a previous study upon the function of the intrinsic muscles of the ear[4] a series of detonation experiments of both the acute and chronic type were carried out. The procedure employed was as follows: The animal was anesthetized, placed in the usual experimental position and covered with a heavy wooden box. In the top of the box a small hole had been made directly over the animal's head and at an equal distance from the two ears. The barrel of a .22 caliber revolver was inserted through this hole and two shots fired in rapid succession. The animals were then allowed to recover from the anesthesia and were tested at varying intervals of time thereafter. The damage produced to the organ of Corti was similar to that described by other investigators (Guild[5]), ranging in extent from destruction of a few of the outer hair cells to extensive destruction of the entire organ of Corti in more or less localized regions. Again depending upon the extent of the damage, the higher frequencies were lost while those in the lower range remained, though lowered in intensity. This was true even though the organ of Corti at the apex had been damaged. No specific effect could be observed so far as the position of maximum pathology was concerned.

Incidentally the milder type of lesion produced in these detonation experiments corresponds very closely to that described in animals subjected to intense sounds over long periods of time. In the majority of this latter group so far reported and tested electrically there has been shown some damage to the outer hair cells, a general lowering in response throughout the entire range of frequencies tested. The lowering in response at the actual stimulating frequency used may have been somewhat greater than for frequencies above and below but not significantly so. (Horton,[6] Davis.[7])

Acute Fatigue Experiments.—Acute experiments in which single frequencies were used at high intensities for periods of from five minutes to two hours, have already been reported.[4] The fatigue developing after such stimulation was in every instance uniform for all frequencies regardless of the stimulating frequency. In general, frequencies below 1000 d. v. were more effective in producing fatigue than were those above 1000 d. v. The duration of the fatigue was directly proportional to the length of time the stimulating tone was used. The fatigue effect could be observed in the experimental ear for three days after exposure to the stimulating frequency. In no instance was there histologic evidence of any damage to the organ of Corti. This uniform fatigue effect to a single stimulating frequency has been observed by several other investigators during the past year. (Wever, Bray and Horton,[8] Finch and Culler.[9])

In addition to studies upon fatigue resulting from stimulation by air, an attempt was made to cause fatigue by bone conduction. During the time limits of an acute experiment it was found impossible to produce auditory fatigue, no matter how intense the stimulation by bone might be .

DISCUSSION.

A considerable variety of experimental procedures designed to demonstrate specific function of different parts of the cochlea have been described. Every type of experiment has been carried out in the acute and chronic manner. The necessity for studying the physiology of the ear in both ways has become more and more apparent, no matter what individual structure was being investigated.

In any discussion of cochlear function two very distinct standards must be considered. Is impairment of function, regardless of the method of measurement, to be regarded as evidence of localization, or must complete absence of transmission of one or more frequencies, coupled with definite histologic change, be the basis of conclusion?

In the present report the second combination of facts has been considered the only conclusive experimental approach. Many factors may contribute towards impairment in transmission. So far as the cochlea is concerned only destruction of the whole or any one of its parts can be responsible for a complete failure to transmit one or more frequencies with high intensity of stimulus.

Clinical observations depend of course on threshold response, but ample evidence is available from audiometer tests controlled by histologic material to demonstrate that when maximum intensity of stimulus fails to elicit some response, usually the organ of Corti, nerve and ganglia, one or all are absent. A possible advantage of the experimental method over clinical observation lies in the fact that the method is purely objective and permits complete control of all source of error. This latter statement indicates of course the necessity of being familiar with the various possibilities of error, electrical, acoustical and mechanical.

If the procedure outlined may be accepted and the findings regarded as accurate as any experimental method permits, the following facts seem reasonably conclusive. Cochlear lesions, whether spontaneous or experimental, invariably result in a loss of the transmission of sound stimuli, as measured by changes in electrical potential, whether picked up at the round window or on the nerve. The two responses are probably identical in nature, the round window response being more intense simply on account of its proximity to the point of electrical discharge and absence of the bony cochlear wall. Albino cats with undeveloped organ of Corti and collapsed Reissner's membrane do not transmit any frequency by either the cochlea or nerve electrode or by bone conduction. In the case of spontaneous atrophy of the organ of Corti, nerve and ganglion, but with a normal Reissner's membrane, little if anything was transmitted. This observation tends to preclude Reissner's membrane as the source of the electrical potential change and indicates the hair cells as the probable origin of the phenomenon. This fact has already been brought out in studies on auditory fatigue and more lately by Davis and his co-workers.[7]

Experimental damage to the organ of Corti, leaving an intact nerve and Reissner's membrane, causes a loss of transmission of the higher frequencies. Depending upon the extent of the lesion, however produced, the higher frequencies are first lost. This fact holds true regardless of the site of the lesion. Extensive lesions may be produced at the apex without losing any frequency from 64 to 4096 d. v.

An intact cochlea seems to be related not only to the range of frequencies transmitted but also to the intensity perceived, this fact, of course, being dependent upon a normal transmitting apparatus. Even with middle ear involvement, low frequencies may be transmitted in the presence of apical destruction. Intense sound stimuli cause an increase in the actual length of vibrations of the basilar membrane, thus in all probability involving receptor cells above and below any given point of damage. This fact, coupled with the observations detailed above, detracts from the conception of strict localization of low frequencies to the apex. The invariable loss of the higher frequencies in the presence of significant damage to the organ of Corti at any point suggests a quantitative relationship between the amount of organ of Corti present and the perceptible frequency range. In no instance have high frequencies been transmitted after loss of frequencies below 1000 d. v. when the experiment was properly controlled for electric and acoustical error.

Of possible significance in clinical otology is the fact already reported that an ear transmitting poorly as a result of middle ear pathology will not fatigue. Since the site of fatigue is the hair cells, were impaired hearing of cochlear origin the ear should fatigue more easily than a normal ear.

CONCLUSION.

No evidence obtained from the procedures described above indicates localization of low frequencies to the apex of the cochlea. Though the apex is doubtless necessary for optimum experimental transmission or clinical perception of tones, any intact portion of the end organ may serve as the receptor of a stimulus of low frequency applied to the ear.

BIBLIOGRAPHY.

1. Howe, H. A., and Guild, S. R.: Absence of the Organ of Corti and Its Possible Relation to Electric Auditory Nerve Responses. Anat. Rec., 55:20 (Suppl. to No. 4), 1933.

2. Hughson, W., Crowe, S. J., and Howe, H. A.: Physiology of the Ear. Acta Oto-Laryngol., 20:9-22, 1934.

3. Hallpike, C. S., and Rawdon-Smith, A. F.: The "Wever and Bray Phenomenon." A Study of the Electrical Response in the Cochlea with Especial Reference to Its Origin. J. Physiol., 81:395, 1934.

4. Hughson, W., and Witting, E. G.: An Objective Study of Auditory Fatigue. Acta Oto-Laryngol., 21:457-485, 1935.

5. Guild, S. R.: War Deafness and Its Prevention—Report of the Labyrinths of the Animals Used in Testing Preventive Measures. J. Lab. and Clin. Med., 4:153-180, 1919.

6. Horton, G. P.: An Experimental Study of Stimulation Deafness in Guinea Pigs. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 44:252, 1935.

7. Davis, H.: The Electrical Phenomena of the Cochlea and the Auditory Nerve. J. Acoustical Soc. of Am., 6:205-215, 1935.

8. Wever, E. G., Bray, C. W., and Horton, G. P. The Problem of Stimulation Deafness as Studied by Auditory Nerve Technique. Science, 80:18, 1934.

9. Finch, G., and Culler, E.: Effects of Protracted Exposure to a Loud Tone. Science, 80:41, 1934.

LXXVIII.

BY T. H. BAST, PH. D., AND J. A. E. EYSTER, PH. D.,

MADISON, WIS.

Wever and Bray originally believed that the phenomenon which they observed with their method was the auditory nerve action current. Subsequent work, however, has shown that the potentials arising within the cochlea are distinct from the action currents in the auditory nerve and pathways.

Since this electrical current picked up from the animal's cochlea or immediate vicinity faithfully reproduces in the loud speaker or ear phones the actual sounds made into the animal's ear, and since it is a vital phenomenon which disappears after the animal is dead, it seems likely that it can be used in studying the function of the various parts of the ear.

From the outset, then, it should be clearly borne in mind that the electrical impulse picked up from the ear by the Wever and Bray method is not a nerve action current, but that it is due to a difference of potential developing at some point in the cochlea associated with sound reception. It may perhaps be the stimulus to the auditory receptors. Considerable difference of opinion exists as to the cochlear structure or structures in which the cochlear potentials arise. One group of workers have recently stated that its origin was in the organ of Corti and that therefore the phenomenon could be taken as an index of the animal's hearing, and that a normal organ of Corti was essential not only for hearing but also for the production of the Wever and Bray phenomenon. Other workers feel that the phenomenon is generated in some membrane of the cochlea but not in the organ of Corti.

With these facts and thoughts in mind, Dr. Eyster and I have employed the Wever and Bray method in an attempt to answer two main questions:

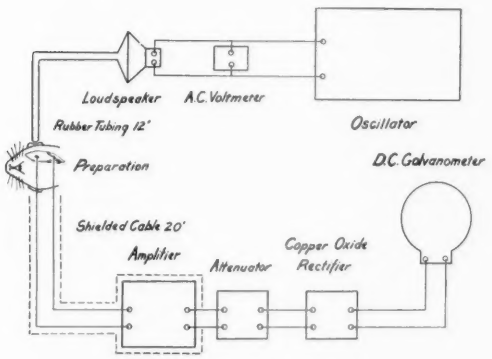

Fig. 1. Diagram of apparatus.

First: Are pure tones of different frequencies selectively picked up from different parts of the cochlea so as to indicate localization of pitch?

Second: Is the Wever and Bray phenomenon dependent upon the structure and integrity of the organ of Corti and, if so, is the phenomenon a true index of the hearing of the individual?

MATERIALS AND METHODS.

Fig. 1 is a diagram of our apparatus. Pure tone frequencies are produced by a General Radio Audio-frequency Oscillator and led through a General Radio alternating current voltmeter, Wright DeCoster Hi-Fidelity type loud speaker and through a rubber tube to the animal's external ear. A ventral neck incision is made and the animal's middle ear opened through the bulla. Two leads, one imbedded in the muscle in the operative field and the other from some specific part of the cochlea, are led through shielded cables to a three-stage amplifier with voltage gain of about 5,000. From here it is led through an attenuator and copper oxide rectifier to a Leeds and Northrup-D'Arsonval wall-type galvanometer. Galvanometer readings for all frequencies used are transposed to either microvolts or decibels and curves plotted.

The animals used for this series of experiments were guinea pigs, because in them all turns of the cochlea can be exposed from the middle ear. At the conclusion of each experiment the ears were removed and prepared for histologic study. We now have serial sections of seventy such ears as histologic evidence for our conclusion.

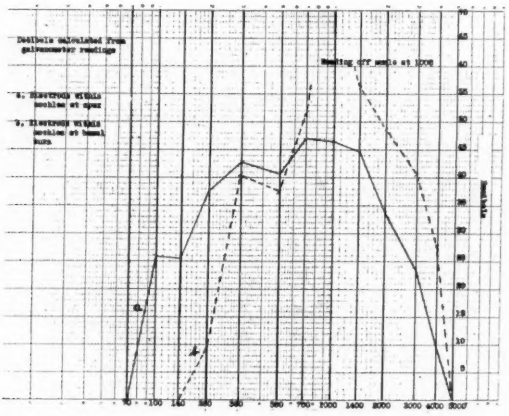

Fig. 2. Graph in decibels showing difference in reception from apex and base of cochlea. a. Electrode within cochlea at apex. b. Electrode within cochlea at basal turn.

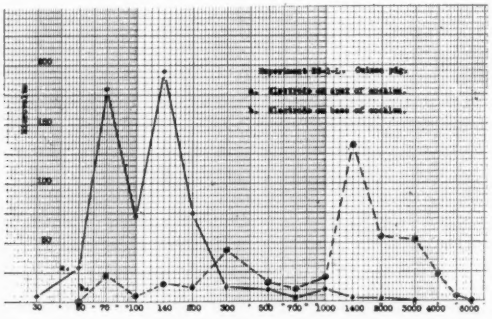

Fig. 3. Graph in microvolts showing difference in reception from apex and base of cochlea. a. Electrode on apex of cochlea. b. Electrode on base of cochlea.

Our experimental procedure and results may be grouped into four parts:

1. *Frequency of localization in apex and base of cochlea.* The active electrode was placed first on or in the apex of the cochlea and the cochlear response, as indicated by the galvanometer, recorded for frequencies ranging from 50 to 5000. The electrode was then placed on or in the basal turn of the cochlea and the response recorded. From a large series of such experiments we can conclude that low frequencies can be picked up more readily from the apex than from the base, while high frequencies are picked up more readily from the base than from the apex. This is shown in Figs. 2 and 3. In Fig. 2 the frequency curves (a) lead from apex and (b) lead from base, are

plotted in decibels. In Fig. 3 the frequency curves are plotted in microvolts. From these curves it will be noted that the peak response from an apical lead lies between 70 and 200 cycles, while from the basal leads the peak is usually at 1400 cycles. In view of the fact that the distance between the apical and basal lead is very small as compared to the distance of either from the indifferent electrode contact, the differences in apical and basal response indicate a rather high degree of localization. That this localization, however, is not absolutely specific is shown by the second series of experiments.

2. *Effect of partial removal of cochlea.* In these experiments the electrode was placed on or just within the basal coil of the cochlea. After a frequency transmission curve was obtained, the apical coil of the cochlea was removed under a dissecting microscope and a second curve was taken. Then the second and third apical turns were removed so that only the basal turn remained without completely obliterating the response. Figs. 4 and 5 are graphs showing the initial frequency curves and also frequency curves after removal of successive turns of the cochlea. Fig. 4 is plotted in decibels, while Fig. 5 is plotted in microvolts.

From these graphs it will be noted that the removal of the apical turn and then the second and third apical turns produced a marked reduction of response to the low frequencies, while the higher frequencies were only slightly reduced.

Like the first series of experiments, this indicates localization of low pitches in the apical turns and high pitches in the basal turns. This localization, however, as shown by the Wever and Bray method, is not specific for low frequencies reception, for low pitch perception is still possible, although reduced, when the apical turn and even the second apical turn has been removed. This would suggest that low pitch perception is localized diffusely in the region of the apex but that it may be perceived although less specifically in turns below the apical.

However, this is not a conclusion, for one must also consider the fact that by removing the apical turn, thus opening the endolymph and perilymph channels, an abnormal condition is produced. This disturbance of the normal pressure relation between endolymph and perilymph and the resulting reduction of pressure on membranes may make possible the reception of low pitches in the middle turns which in the normal condition would be perceived only in the apical turn. The fact, however, that the curve for high frequencies is little disturbed by opening the cochlea argues against this possibility.

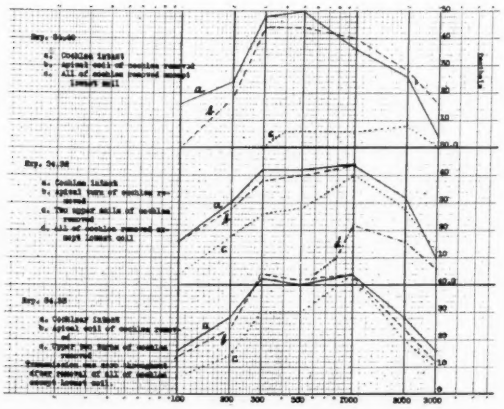

Fig. 4. Graphs in decibels showing effect of removal of successive turns of the cochlea. Exp. 34.40. a. Cochlea intact. b. Apical coil of cochlea removed. c. All of cochlea removed except lowest coil. Exp. 34.32. a. Cochlea intact. b. Apical turn of cochlea removed. c. Two upper coils of cochlea removed. d. All of cochlea removed except lowest coil. Exp. 34.33. a. Cochlea intact. b. Apical coil of cochlea removed. c. Upper two turns of cochlea removed. Transmission was zero throughout after removal of all of cochlea except lowest coil.

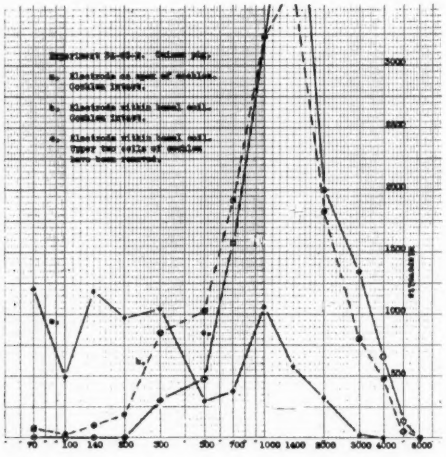

Fig. 5. Graph in microvolts showing effect of removal of the two apical turns of the cochlea. a. Electrode on apex of cochlea. Cochlea intact. b. Electrode within basal coil. Cochlea intact. 3. Electrode within basal coil. Upper two coils of cochlea have been removed.

Fig. 6. Photomicrograph of cochlea from which the two apical turns are removed. There is a puncture hole in the basal turn in region of cochlear duct (at right). In spite of all the damage the reception was still fairly good. (G. P., 34-61 left.)

Fig. 6 is a photomicrograph of a guinea pig cochlea which had the two apical turns removed. In spite of the considerable damage the response was still good for high frequencies but markedly reduced for the low.

3. *Effect of organ of Corti atrophy on transmission.* In order to further localize pitch, a study was made of the frequency curves in relation to atrophy of the organ of Corti. This study showed that normal transmission curves can be obtained in the guinea pig when there is complete atrophy of the organ of Corti in all turns except a small part of the basal turn. On the other hand, defective frequency curves were obtained when the organ of Corti appeared normal throughout the cochlea. Fig. 11 shows a normal frequency curve taken from the ear of a guinea pig in which the organ of Corti was completely atrophic as shown in Fig. 7. This organ of Corti should be compared with a normal one shown in Fig. 8. In Fig. 12, curve (a) is taken from the left ear of guinea pig 34-64, whose organ of Corti was normal (see Fig. 9), while curve (b) is taken from the right ear of the same animal whose organ of Corti is atrophic in all turns except part of the basal turn (see Fig. 10).

It is apparent then that the integrity of the organ of Corti is not essential to the production of the Wever and Bray phenomenon

Fig. 7. Photomicrograph of G. P. 35-10 left, showing atrophic organ of Corti. This ear gave normal frequency curve. (See Fig. 11.)

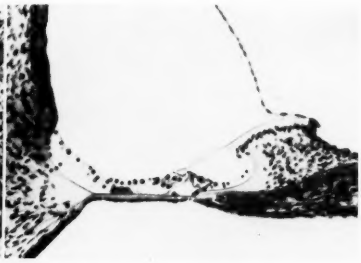

Fig. 8. Photomicrograph of a normal organ of Corti. (G. P., 34-59 right.)

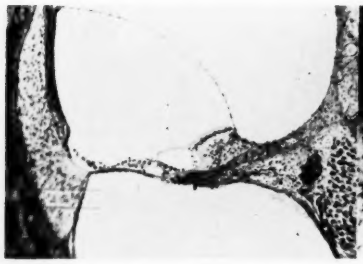

Fig. 9. Photomicrograph of organ of Corti of left ear of G. P. 34-64. (See Fig. 12.)

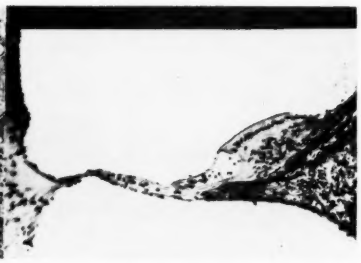

Fig. 10. Photomicrograph of organ of Corti of right ear of G. P. 34-64. (See Fig. 12.)

and that therefore the Wever and Bray phenomenon is probably not an index of the actual hearing of the animal. It is further evident that pitch localization as determined by this method cannot be located in the organ of Corti. The Wever and Bray phenomenon, however, while not dependent on the integrity of the organ of Corti, may well depend on the integrity of other structures which are intimately related and necessary to hearing. The source of the cochlear current then must be looked for in some other structure of the cochlea or in a fluid pressure relationship across some membrane.

In several of our animals the transmission of all frequencies was markedly reduced. In these animals the organ of Corti was markedly atrophic and Reissner's membrane was collapsed and fibrosed on to the organ of Corti. In these cases it was very likely a combination of pathologic factors that caused the poor conduction and not the condition of the organ of Corti alone. It is this combination of pathologic factors that may be the cause for the lack of transmission observed in deaf albino cats rather than the atrophic organ of Corti

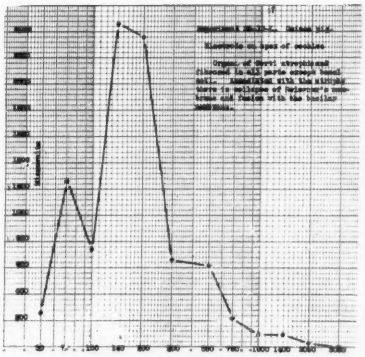

Fig. 11. Graph showing normal reception curve of a cochlea in which the organ of Corti is atrophic. (See Fig. 7.) Electrode on apex of cochlea. Organ of Corti atrophic and fibrosed in all parts except basal coil. Associated with the atrophy there is collapse of Reissner's membrane and fusion with the basilar membrane.

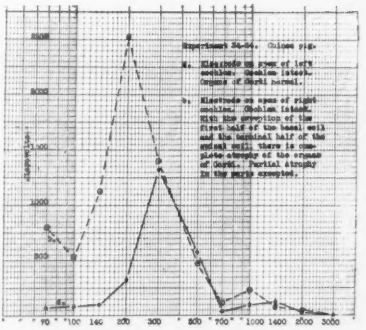

Fig. 12. Graph showing frequency curve of both right and left ears of G. P. 34-64. The right ear which gave good reception had an atrophic organ of Corti, while the left with poorer reception had a normal organ of Corti. a. Electrode on apex of left cochlea. Cochlea intact. Organ of Corti normal. b. Electrode on apex of right cochlea. Cochlea intact. With the exception of the first half of the basal coil and the terminal half of the apical coil there is complete atrophy of the organ of Corti. Partial atrophy in the parts excepted.

alone. In these last named cases, where Reissner's membrane is collapsed and fibrosed to the organ of Corti, it seems likely that a disturbance of the pressure relationship between the otic and periotic fluid has occurred. The next series of experiments were designed to throw further light on this question.

4. *Effect of puncture of the cochlear canals.* In this series of experiments small holes were drilled either into the scala tympani, scala media or scala vestibuli or into several or all of these by means of a fine needle drill. The drill point measures about .1 to .2 millimeters in diameter and was operated either by hand or by dental motor. These punctures may be divided into four groups as shown in Fig. 13. The greatest difficulty was encountered in opening the cochlear duct without opening also the scala vestibuli. The stria vascularis is so loosely attached to the capsular bone that even with a very pointed drill it pushed ahead of the drill and ruptured into the scala vestibuli. Thus in most of the attempts to open the scala media the scala vestibuli was also opened either by rupture or by extension through Reissner's membrane. We have fourteen cases of this type. In six other cases all three ducts were opened. The results in these twenty cases are essentially the same. There was an initial drop in the transmission to two-thirds to one-half the original intensity and then a rapid rise to somewhat below the original intensity. The low fre-

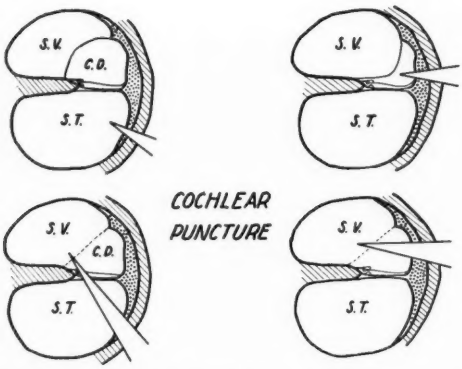

Fig. 13. Diagram to show the different types of drill punctures made into the cochlea in different guinea pigs.

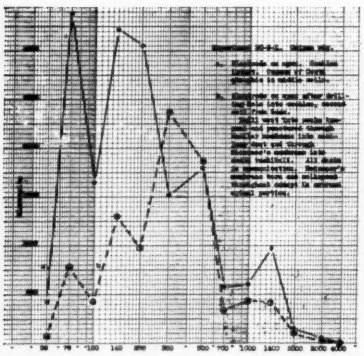

Fig. 14. Graph showing two frequency curves of G. P. 35-8. Left. (a) Normal curve. (b) after drill hole of type shown in Fig. 13-C. a. Electrode on apex. Cochlea intact. Organ of Corti atrophic in middle coils. b. Electrode on apex after drilling hole into cochlea, second coil from base. Drill went into scala tympani and punctured through basilar membrane into cochlear duct and through Reissner's membrane into scala vestibuli. All ducts in communication. Reissner's membrane torn and collapsed throughout except in extreme apical portion.

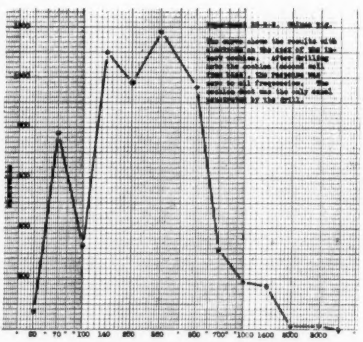

Fig. 15. Graph of frequency curve of C. P. 35-6 Right. There was no response after hole was drilled. (See Figs. 17 and 18.) The curve shows the results with electrode on the apex of the intact cochlea. After drilling into the cochlea (second coil from base), the response was zero to all frequencies. The cochlear duct was the only canal penetrated by the drill.

quencies from 50 to 200 suffered more than the higher ones. A typical example of this series is G.P. 35-8, left, where all turns were opened. The original transmission curve and the curve following puncture are shown in Fig. 14. Fig. 16 is a photomicrograph of a section through the puncture site showing all three scalæ in communication.

The attempt to puncture the cochlear duct without opening the scala vestibuli was successful in only two cases. In one of these the hole, however, was so small through the stria vascularis that it is questionable whether much fluid was lost. The lips of the puncture hole were shown to be in apposition in the histologic sections and Reissner's membrane was only slightly dished in.

In one case, however, the opening into the cochlear duct was clear cut. In this case, G.P. 35-6, right, the transmission was completely abolished after the puncture. Fig. 15 is a curve of the transmission of this ear before the puncture. Fig. 17 is a low power and Fig. 18 is a high power photomicrograph of this cochlea showing the puncture hole. Note that in Fig. 17 the Reissner's membrane is collapsed in all turns below the hole. In this ear the sacculus is also collapsed while the utriculus is open. While this one clear-cut case is extremely interesting it is essential that more successful results like this one must be obtained before conclusions can be drawn. However, there is the suggestion that the response obtained by the Wever and Bray method is dependent upon certain pressure relations between otic and periotic fluid. In the latter case there is a clear cut imbalance while in the other cases, where the otic and periotic canals are both opened only at the site of puncture, a balance can still be maintained in the remaining turns. Definite localization must await further results.

From a practical standpoint, these results suggest that deafness may be due not only to middle ear pathology (conduction deafness) or to nerve pathology (nerve deafness), but that deafness may be due to a pathology in certain structures or pressure relationships in the cochlea which are responsible for the cochlear potentials which may mediate between the physical vibrations and nerve action currents.

CONCLUSIONS.

1. That cochlear currents developed in response to sound impressed on the ear depend upon retention of certain pressure relations across certain membranes in the cochlea. Considerable differences in relative pressure between the endolymph and perilymph greatly reduce or abolish the response.

2. Localization does occur in the cochlea. Low frequencies are more readily picked up from the apex and high frequencies from the base of the cochlea. This localization is not absolutely specific for a considerable part of the apical portion of the cochlea and may be

Fig. 16. Photomicrograph of second basal turn of cochlea of G. P. 35-8 Left, showing extent of injury of drill hole.

Fig. 17. Low-power photomicrograph of cochlea of G. P. 35-6 Right, showing drill hole. Note collapse of Reissner's membrane in turns below hole.

Fig. 18. Higher power photomicrograph of part of Fig. 17, showing the drill hole into cochlear duct. Response was completely abolished after drill hole was made.

removed with retention of response of intermediate and high frequencies.

3. Integrity of the organ of Corti is not essential to the production of the cochlear response in the guinea pig, since normal response can be obtained when these structures are in large part atrophic. In certain cases, however, the response is much reduced or absent when there are a combination of extensive pathologic changes in the cochlea, such as advanced atrophy with fibrosis, collapse and adhesion of Reissner's membrane and fibrosis in the basilar membrane. It is this combined pathology that appears responsible for the reduced conduction rather than the absence of sensory cells of the organ of Corti.

LXXIX.

By Simon Dworkin, M. D.,*

Montreal, Canada.

(By Invitation.)

The results presented here were obtained in the course of investigation of hearing acuity: first, in normal cats; secondly, in cats after middle ear damage; and thirdly, in cats after damage to the cochlea. The work is still incomplete, so that our contribution to the discussion may not be as pertinent as one could wish.

The general procedure for testing hearing in normal, active cats has already been described. Owing to the inadequacies of available loud speakers, our quantitative work has been confined to frequencies between 100 to 16,000 cycles per second. We have repeatedly found that the upper hearing limit of the cat is much beyond this latter figure; undoubtedly it exceeds 30,000 cycles per second.

An unexpected problem that came up during the measurement of hearing was the changed reactions of the animals. Biologically, tests of hearing acuity involve responses to threshold sound stimuli. For this, the cats must be thoroughly conditioned beforehand; they must be in perfect health, and they must be fairly but not too hungry. Sooner or later all cats subjected to this training regime broke down—underwent what could, after Pavlov, be called a "neurosis." Fortunately, complete recovery occurred after several days' rest. Another precaution that must be taken is to condition the animals to stimuli involving receptors other than the ear, such as light, and

*Department of Physiology, McGill University.

tactile stimuli. This serves two purposes: (1) it lessens the nervous tension of the waiting between threshold stimuli; (2) it provides a check when hearing, for some reason or other, seems absent. Thus, when the sound is too weak to be heard and yet a light stimulus brings out a response, one may conclude that the absence of response to the weak sound is not due to general loss of reactivity. In later

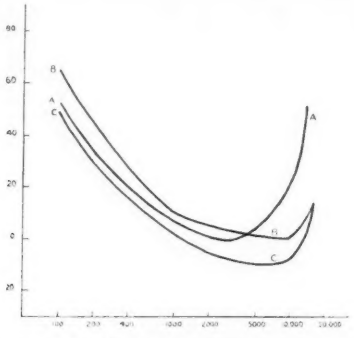

Fig. 1. A comparison of the threshold-frequency curve of man (curve A) with that of two cats (curves B and C). The abscissae refer to cycles per second, which are plotted logarithmically, as usual. The ordinates represent intensity thresholds. These are computed, at each frequency, from the strength of the current passing through the speaker. The current value equivalent to the most sensitive threshold of man (3000 c. p. s.) is called 0 decibels. The other figures were derived from the ratios of the respective current strengths, on the basis of $20 \log \frac{1}{I^2}$. Note the greater acuity of the cat's hearing at the higher frequencies.

experiments, when hearing was, for one reason or another, impaired, again the additional stimuli were of value as controls.

As to the production and measuring of the sound energy at the various frequencies, it must be remembered that accurate studies of hearing acuity, even in man, present difficulties. Our final figures were arrived at by indirect calculations of our experimental results and by reference to the figures of Sivian and White in man. A more satisfactory way would be to measure directly the intensity of the sound emitted by the loud speaker; so far we have not had the necessary equipment.

Fig. 1 represents audiograms of two cats, compared to that of man, as determined by our method. In these cats, one ear only was used, the other having been completely deafened. Our figures for man were obtained on healthy young students. Thus we have a comparison of monaural hearing in cats with binaural in man. Under these conditions it appears that for the lower frequencies (100 to

3000 cycles) the cat's hearing is about the same as that of man. In the latter, our results agree with those of Sivian and White, and show the greatest sensitivity to lie between 2000 and 3000 cycles. This point of maximum intensity we have plotted as 0 decibels. At 5000 cycles the threshold for man begins to rise appreciably; at 10,000 cycles it is 22 decibels above the zero point; and at 14,000 it has increased to between 50 and 60 decibels above this point. What is interesting is that in the cat the sensitivity is still at its lowest between 5000 and 10,000 cycles. Some animals show even greater sensitivity at 10,000 than these two cats; the lowest figure at this frequency in some cases was 20 decibels below the maximum sensitivity for man

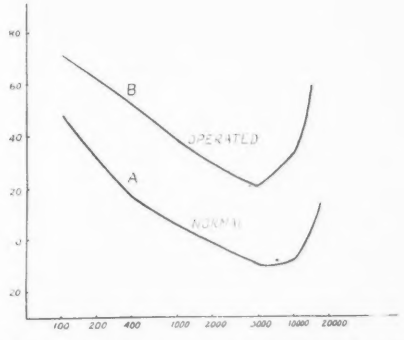

Fig. 2. The threshold-frequency curves of a cat, determined before and after production of middle ear deafness.

at 3000. From this lowest point the rise in threshold is very gradual. At 16,000 cycles the threshold for the cat never exceeds 14 decibels above the most sensitive point. One may conclude, therefore, that for the upper frequencies the hearing of the cat is much more acute than that of man. This is in accordance with previous findings on the higher upper limit of hearing in cats.

The operations, whether on the middle ear or the cochlea, were all done under strict asepsis. The approach to the ear structures was through the mastoid bulla.

In the middle ear our objective was to put the accessory structures of hearing out of function. This was done by removing at least the malleus—sometimes the incus, with an unknown amount of damage to the stapes and perhaps the oval window. The hearing acuity before and after two such operations in one cat is shown in Fig. 2. In this sort of middle ear deafness we still get a fairly smooth audiogram, the general shape being very similar to the normal. This

shows that the changes of sensitivity above basal at the various frequencies are not a function of the accessory mechanism of hearing. Next, we see that for all frequencies the sensitivity is, as expected, greatly diminished. At 100 cycles there is a difference of 24 decibels; at 5000 cycles, 31 decibels, and at 14,000, 57 decibels. One may say that at 10,000 and 14,000 cycles the hearing of a cat without ossicles is reduced to that of man.

Our attempts to produce localized tone loss in the cochlea itself have so far been unsuccessful. We have operated upon twelve well-trained animals. In the first nine we attempted to bore a very small hole (using the smallest drill obtainable) into the apex of the cochlea.

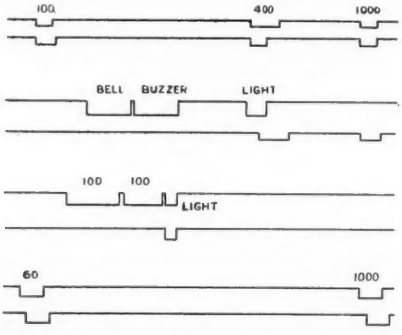

Fig. 3. Records of responses to various stimuli by normal and operated cats. The breaks in the upper levels represent the occurrence of the stimuli; those in the lower lines, the responses. Record 1 shows responses of a cat with one normal ear to frequencies of 100, 400 and 1000 cycles. Records 2 and 3 were taken from the same cat, after a minute perforating lesion in the apex of the remaining cochlea. Responses to a bell, buzzer or a tone of 100 are absent, while responses to light stimuli are prompt.

Record 4 is from a cat after two shallow, non-perforating holes had been drilled in the bone near the apex and cautery applied. The responses to tones of 60 and 1000 cycles are perfectly normal.

Sometimes the perforation was made in the lateral (external) aspect of the apex; at other times at the ventral surface. The depth of the hole was varied from the most superficial to the maximal depth. In all cases, complete deafness resulted. That the fault was not one of breakdown of the conditional processes was easily found by the ready responses to other stimuli. This is shown in Fig. 3. We therefore are forced to conclude that even a small, local perforating lesion in the cochlea produces total impairment of hearing. Further light on the extent of the damage will have to await histologic examination.

Later, it was possible to condition the animals to respond to very loud musical sounds—so loud as to produce palpable tremors. The frequency limit of these responses lay between 30 and about 1000 cycles, never above. The intensity thresholds have been determined

in dial settings, but not as yet in absolute units. We have come now to recognize this type of response as diagnostic of total cochlear deafness in cats, as distinct from middle ear deafness.

Finally, we have attempted to produce more superficial lesions in the cochlea by boring part way through the covering bone and applying a cautery to the bone overlying the cochlea itself.

CONCLUSIONS.

The monaural audiogram of the normal cat reaches its greatest sensitivity between 5000 and 10,000 cycles. Between 100 and 3000 it is similar to that of man. From 5000 upwards the threshold in the cat is much lower.

In experimentally produced middle ear deafness, a changing frequency-intensity curve is still obtainable, though the thresholds at all frequencies are raised.

Even small perforating lesions, made in the apex of the cochlea, result in complete cochlear deafness. A characteristic response to tremors can be obtained in these cases. So far as they go, these results argue against low-tone localization in the apex of the cochlea.

LXXX.

By E. A. Culler, Ph. D.,*

Urbana, Ill.

(By Invitation.)

In this symposium on localization I am doubtless expected to report on tests of hearing. Our results in this case were, however, secured by the Wever-Bray technic, not because of any change in my conviction that tests of hearing are always fundamental in otologic work, but simply because in this problem the electric method is more simple and direct

The question is, what does the cochlea do with the frequencies impressed upon it, in particular those below 1000 cycles? This question has two aspects:

(a) Does each frequency have some kind of focus or resonance point?

(b) If so, where do these various foci reside?

*Communication No. 18 from the Animal Hearing Research, Department of Psychology, University of Illinois. This investigation was maintained with aid from the Research Council of the American Otological Society.

A good many ways of attacking this problem have been used hitherto; most of them, indeed, are represented in our discussion today. Of these may be mentioned: (1) stimulation deafness, in which the lesion is produced by means of intense or protracted acoustic stimulation, and then correlated with associated losses in hearing and in cochlear potentials; (2) introduction of drugs through the round window or through small punctures in the bony wall; (3) mechanical lesions from thrusting a drill into some part of the cochlear spaces; (4) scorching with an electric needle. These methods give excellent service, but they all have one defect in common: the cochlea is obviously not intact or normal after it has been scorched, drilled, drugged or otherwise injured. In puncturing the wall or coagulating the cochlear fluids, we are always beset with the fear that we have changed, in some unknown and unknowable way, the very characteristics of the cochlear system which we are trying to measure. From the laws of hydrodynamics, we know that the behavior of fluid in a closed oscillatory system like the cochlea can be greatly modified by introducing even a tiny hole somewhere in the containing walls. In our laboratory we have sampled almost every one of these localized lesion methods, but have always been troubled with the fear that in so doing we were introducing indeterminate errors into our procedure. We can confirm, what has been so clearly described here today, that some electric response remains even after one or two whole turns have been cut off the apex; but unhappily we have no assurance at all that the locus or pattern of response is even remotely the same after these drastic operations.

In view of these considerations, we decided to work only with the intact mechanism. The bulla was opened in the guinea pig on the ventral side, thus exposing to view the middle ear and cochlea, as shown in Fig. 1. As you know, the guinea pig cochlea is particularly suited for experimental work. It has from four to four and one-half turns, and is unusually accessible, projecting from the petrous bone like a thumb. All observations were made on the cochlea as thus exposed; the whole working mechanism, from tympanum through ossicles to cochlea and nerve, being in every respect normal. This is emphasized because it is the distinctive feature of our procedure. A sharp tungsten wire was applied in turn to a number of carefully localized points on the cochlear wall. Fig. 2 is an outline drawing of the cochlea, numbered to indicate all the points where the electrode was placed and the response measured. You see one row of points on the mid-ventral aspect directly facing us (Nos. 18 to 24), another row along the lateral side next the tympanum (Nos. 10 to 17), and

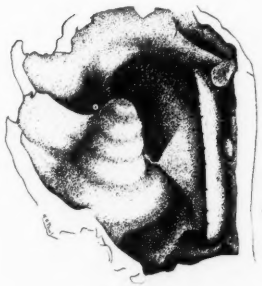

Fig. 1.

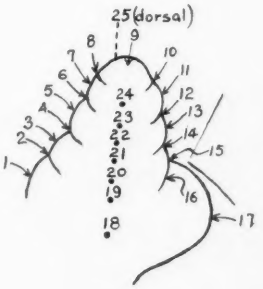

Fig. 2.

a third row on the medial aspect, just one-half turn (180°) from the lateral side (Nos. 1 to 8). To illustrate our procedure, assume the animal to be immobile in a holder, with the exposed middle ear dry and warm. The ground electrode is placed on some adjacent muscle, and the active wire electrode (covered with a film of oil to minimize condensation of moisture from the air) is carefully set on point No. 22 (midventral aspect, fourth apical turn). When the sound tube is adjusted and everything rigidly clamped, the tests begin. The following series of twenty tones were regularly used:

125	400	1000	3500
150	500	1500	4000
200	600	2000	5000
250	700	2500	6000
300	800	3000	7000

The oscillator is set for 125 cycles. The electric output, before reaching the speaker, passes through an attenuator by means of which the intensity can be reduced in any amount from 1 to 127 decibels. We now feed a weak tone of 125 cycles into the guinea pig's ear. This produces the usual cochlear response, which is picked up by the tungsten electrode on point No. 22 and transmitted through the amplifiers into a so-called "tube voltmeter." As the name indicates, this instrument measures the voltage picked up at the electrode; the potential can be read quickly and accurately from the dial, which is far more convenient to use than telephones or bridges. Since very loud sounds introduce harmonics and may even injure the ear, we always work with minimal intensities. I fully agree with Drs. Davis and Lurie that low stimulus intensities must be used in this work for reliable results. A small deflection of the voltmeter (from zero position of the needle up to a given mark) was arbitrarily fixed as the "threshold response" of the cochlea. You will observe that this

procedure is directly analogous to methods used in measuring hearing. When you measure a patient's hearing with an audiometer, you reduce the sound intensity until it is just barely loud enough to evoke a response ("yes"). Likewise here we attenuate the sound energy until it is just strong enough to bring the needle up to our threshold mark; we then record in the protocol just how intense was the sound required to give this threshold reading. Having secured the threshold figure at 125 cycles, we proceed to 150, and so on throughout the entire list. We now have the cochlear response to every one of the twenty tones, as registered from point No. 22. To assure ourselves that this list of twenty readings is really dependable, however, we repeat the entire set. If the second reading for each tone is the same within two decibels, the value is accepted as correct; if the

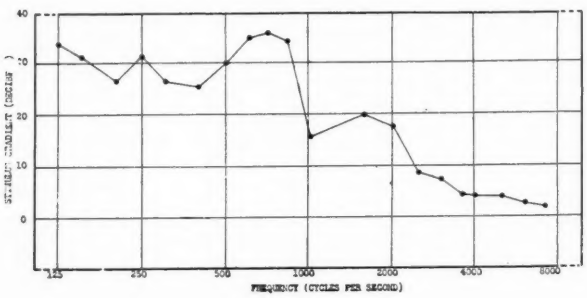

Fig. 3.

second reading differs by more than 2 db, we check the condition of ear and electrode and repeat the series until each pair of readings checks within 2 db. The utmost precaution is needed because a very slight change (e. g., a drop of fluid at the tip of the electrode) alters the readings by 5 or 10 db. To get a double set of readings from each point, we have to take as many as 1,000 readings from the same cochlea.

Having assembled the figures for each point and for all the frequencies, we proceed to analyze them. Where, if anywhere, does each frequency develop the maximal potential? Is there a particular locus where each tone shows the greatest effect? Some of the gross differences are quite obvious. Consider Fig. 3. In passing from point 18 on the basal turn up to point 22 on the third turn, we find the high frequencies falling off markedly and the lower tones coming through stronger; the maximal gain being, as you see, near 700 and the low point around 6000 to 7000. This clearly suggests that 6000-7000 must be near the point of departure (No. 18) and 700-800 near the

point of arrival (No. 22). Now consider another typical case (Fig. 4). We pass through 180° from medial to lateral side of third turn (point 4 to point 14). The low point is 500 and the high point 1000 with a sharp gradient joining the two. This suggests that in going from point 4 to point 14 we are moving away from 500 cycles and toward 1000; in other words, 500 is near point 4 on the medial side and 1000 is near point 14 on the lateral side.

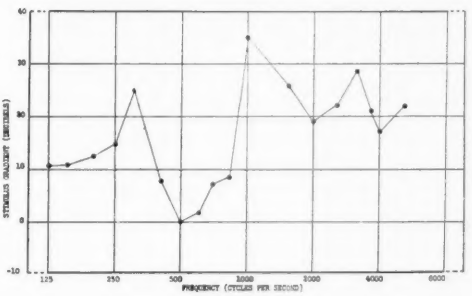

Fig. 4.

It is thus clear, by gross analysis, that certain frequencies are focalized at certain points; but to make a really accurate map of the cochlea we must resort to more detailed and careful examination of our figures. Suppose we consider point 22 (middle of third turn). It is surrounded by a ring of other points, in order: 24, 6, 5, 4, 20, 14, 13, 12. Now if a single frequency is focalized at 22, the magnitude of its electric response ought to decrease if we move away from 22 in any direction whatsoever. Let us see whether any frequency meets this condition. Consider this table (Table 1) of frequencies from 500 to 1000 cycles. We might include all the frequencies, but that would make our table large and confusing. Fig. 4 shows us that this point lies somewhere between 500 and 1000; hence the present table will be quite adequate and will serve better to illustrate our analysis. In passing from 22 to 24, the minimal electric potential, as you see, is generated at 700 to 800 (0); from 22 to 6, at 800 (-2); from 22 to 5, again at 800 (-3); from 22 to 4, again at 800 (-7); from 22 to 20, once more at 800 (-2); from 22 to 14, the minimum occurs at 700 (1); from 22 to 13, at 600 and 700 (-2): from 22 to 12 finally, again at 800 (3). Adding the figures for the eight cases, we find that whereas the electric potential at the surrounding points is on the average greater by 3.9 at 500 cycles and by 2.0 at 600 cycles and much greater at 1000 (6.75 units), it is definitely lower at 700 and 800 (-0.62 and -1.00). What does this mean? After careful con-

TABLE 1.

Gradient		Frequency				
From	To	500	600	700	800	1000
22	24	4	2	0	0	7
22	6	6	5	0	—2	8
22	5	8	5	—1	—3	10
22	4	3	—2	—6	—7	7
22	20	0	0	—1	—2	2
22	14	3	2	1	3	10
22	13	0	—2	—2	0	1
22	12	7	6	4	3	9
Sum		31	16	—5	—8	54
Mean		3.9	2.0	—0.62	—1.0	6.75

sideration I can find but one possible meaning in it: that point 22 is located near the focus of 700 and 800 cycles, probably between the two but nearer 800 (say 775). The result is that whenever you move the electrode away from point 22 the response from 700 and 800 lessens, whereas the other potentials are augmented or remain the same.

By using the procedure just described, we have located each of the frequencies shown in Fig. 5. The diagram is drawn to four and one-half turns. I am never quite sure, when looking at a guinea pig's cochlea, whether it has four, four and one-quarter or four and one-half turns; but in any event the number lies within that range. Starting from the round window, we find 6000 at the midventral aspect of the basal turn. The first complete turn brings us to about 2800. The second whole turn reaches down to a value between 800 and 1000, say 875; the third turn ends between 250 and 300 (circa 260); the fourth turn finally at the very apex terminates near 75.

No claim is made that this map is wholly accurate; but we are able to say something about the degree of error in our locations. We have, for example, fourteen independent estimates of the focal frequency at point No. 24; how well do these fourteen estimates agree? This is their distribution:

In 2	cases	the	estimate	falls	at	125
2	"	"	"	"	"	150
7½	"	"	"	"	"	200
1½	"	"	"	"	"	250
1	"	"	"	"	"	300

The average of these fourteen cases proves to be 195, and the standard error is about 12.7. We can say then with virtual certainty that point 24 falls between 195 plus 25 and 195 minus 25. The greatest possible error in our location is about 10 or 12 per cent.

Fig. 5.

In reply to the question of this symposium, then, let me state my conclusions in two propositions:

(a) Each frequency within the audible range has its own focus of response within the cochlea, this focus being revealed by the electric potentials which can be shown to be maximal for a single frequency at a given site.

(b) The location of this focal point can be fixed within a maximal error of 10 or 12 per cent.

So many divergent results, secured by approved methods, have been reported here today that no one can afford to be dogmatic in this complicated problem. I was happy to find myself in substantial agreement with Drs. Davis and Lurie. My results, of course, shed no light on the mechanism by which the electric potential of the cochlea is generated; but they do indicate that each frequency has a focal electric response and that the site of this focal response can be determined.

LXXXI.

By Edward McCrady, Jr., M. D.,*

Philadelphia.

Almost every possible method of studying localization in the cochlea has been reported upon this morning except that of approaching the problem from the embryologic point of view—finding out whether an animal develops the capacity to hear any one range of pitch earlier than another, and, if so, how its range of hearing is subsequently extended, at the same time examining the microscopic structure of the receptor mechanism to see whether any significant

*From the Wistar Institute of Anatomy.

relation may be found between the development of visible structure and the development of function. This is the method which Dr. Olof Larsell and I employed last summer at the Wistar Institute to investigate localization in the cochlea of the opossum. Our work can not be considered finished at this time, but inasmuch as it represents a new approach which has already yielded enough results to indicate its usefulness, perhaps it will be of interest to give a summary report upon it now.

For about a year and a half I have been engaged in preparing a book on the embryology of the opossum. Many of the points of interest in this study center about the fact that, being a marsupial, the opossum is born in what for a mammal is a singularly embryonic condition. Many of its organs are far from finished when it leaves the uterus and begins to breathe air and derive its nourishment from the mammary glands of its mother.

(Slides were exhibited, showing the external characteristics of the embryo during the last four days of gestation.)

The eye and most of the mouth and also the external auditory meatus, all of which were clearly visible as late as the end of the twelfth day, have become covered over during the last day of gestation by a very thick protective skin known as the epitrichium, so that at birth the external auditory canal cannot be recognized at all. I shall refer to this again a little later. The point of interest is that the first anlage of the inner ear, the acoustic placode, may be recognized as a thickening of the epidermis just lateral to the wide-open medullary plate and medial to the heart tubes. The next slide shows a cross section directly through the middle of the two placodes. Here may be recognized the relatively flat medullary plate, the otic placodes, and immediately beneath the latter the neural crest cells which represent the primordium of the acoustico-facial ganglion. The third slide shows a series of reconstructions of later stages illustrating the development of the external features of the membranous labyrinth up until one week after birth. Most of this development is essentially the same as that of man and other mammals. The semicircular canals, for instance, develop in the well known sequence—anterior canal first, posterior canal second, lateral canal third. The one essential difference is in the relation of this sequence of developmental changes to the time of birth. In man the membranous labyrinth at six weeks (20 mm.) has attained approximately the same stage of development that the opossum shows at birth; but man is not born until forty weeks, which time, according to the same scale, must correspond to about the seventy-three after the birth in the opossum. In other

words, according to the human scale, about the last five-sixths of the embryology of the ear of the opossum occurs after birth while the "embryo" is occupying the pouch. This fact is of considerable practical utility, as it enabled us to test the hearing of the embryos at freqent intervals and to remove one at a time for sectioning.

The experimental procedure was very simple. We did not have any elaborate apparatus, as we undertook these tests only incidentally during an entirely different research program. The mother was held on her back and her pouch was opened, exposing all the nursing young to view. An instrument known as an organette and having a range of three octaves (from 259 d. v. to 2069 d. v.) was used to sound different notes suddenly. The end of the instrument was so directed that there could be no rush of air into the pouch. Each time a note was sounded suddenly the members of a control litter, which were seventy-one days of age at the beginning of the experiment, would all make a startled jump. Sufficient time was allowed between signals to eliminate fatigue or adaptation and to make the succeeding signals as unexpected as possible. It is fortunate that all newborn mammals are startled by sudden sounds. This fact, based upon one of the only two known hereditary or instinctive fears, must, I believe, afford a better criterion of hearing than any element in the complicated and confusing behavior of adults. But the statement that a reflex jump in response to sudden sounds is characteristic of all newborn mammals must be qualified to this extent—the response obviously cannot occur until the mechanism for receiving the stimulus is developed. In the opossum, which is a marsupial, this mechanism is not complete until a considerable time after birth, as will be seen from the following.

At birth the cochlear duct has made about one-half of a turn. It contains no recognizable rudiment of an organ of Corti unless the slightly thicker epithelium of the tympanic wall be taken as such. There are no scalæ, hair cells, tunnel of Corti, or tectorial membrane; so it is not surprising to find that no response of any sort is made to any auditory stimulus at this time. In fact, it was not until fifty days after birth that the pouch young responded to sound, and then it was to a shrill whistle of about 1305 d. v. (E″ on the tempered International Musicians Scale). During the succeeding five days we were able to get them to respond to successively lower and lower notes until we had followed the extension of the auditory range down to middle C (259 d. v.). At the same time the auditory range extended upward to C‴ (2069 d. v.), so that all three octaves were explored in our tests. This constitutes a summary of our knowledge of the functional development of the ear after birth.

The next subject of interest is the morphologic development which accompanies or probably determines this development of behavior. The last figure shows a reconstruction of the membranous labyrinth eight days after birth. It will be noticed that two important external changes have occurred in the cochlear duct. It has grown out to one and one-half turns, and it has begun to separate from the sacculus. The lagena or apical tip is still actively growing. The vestibular part is just completing the growth which will soon separate it from the sacculus everywhere except at the very slender canalis reuniens. The only part of the duct which has already ceased to grow is the second half of the first turn. This region, which ceases to grow first, correspondingly gets a "head-start" in differentiation. An indication of the latter is the appearance of the first rudiment of a tectorial membrane at this point at this time. The gelatinous coat of mesenchyme around the cochlear duct is beginning to be resorbed, but the spaces thus produced are irregular and discontinuous.

At sixteen days of age the cochlear duct has completed the two and one-quarter to two and one-half turns characteristic of the adult. The scalæ, which first formed at twelve days in the second half of the first turn, by a confluence of the irregular spaces mentioned above, now extend throughout the first turn, and one of them, the scala tympani, reaches a little way into the second turn. The tunnel of Corti has also appeared in the first turn and is extending a short distance into the second turn. The tectorial membrane is rather well developed throughout the first turn and can be recognized through the first half of the second turn, but is absent beyond this point. The organ of Corti is most advanced in the second half of the first coil.

At twenty-nine days of age nerve endings are present in this same precocious region. Slide 4, which is taken from a pyridine silver preparation, shows the typical basket-shaped nerve endings about the bases of the three outer and one inner hair cells. From these cells hairs may be seen beginning to grow out. This section passes through the second half of the first coil. In the apical coil no nerve endings can be seen at this time.

By forty-three days of age the entire nervous mechanism for hearing, including the lateral lemniscus to the midbrain acoustic center, is complete. And also the external auditory meatus, which was closed at birth by epitrichial cells, is at last open again. However, all of our tests show that hearing is not yet possible. The only structure which is still unfinished is the end organ, the organ

of Corti. This seems to me of particular interest in connection with an earlier report in today's program. Dr. Bunch described human patients in which the entire organ of Corti was absent in all coils of the cochlea, but the cochlear nerve was intact, and hearing was possible. In the opossum the nervous apparatus is complete for about a week before hearing is possible, and function seems to wait not only upon the presence of an organ of Corti, but even upon the last subtle steps in its differentiation.

When hearing does begin on the fiftieth day, it is at first limited to one note, E″ (1305 d. v.). At this time the organ of Corti seems to have attained the adult condition only in the second half of the first coil. This is the same precocious region where the tectorial membrane first formed, eight days after birth, where the tunnel of Corti first appeared two weeks after birth, where the scalæ first appeared sixteen days after birth, where nerve endings and hairs first appeared twenty-nine days after birth, and where, at last it seems, function first begins fifty days after birth.

According to this evidence, notes of about 1305 d. v., rather high notes in the third octave above middle C, must be received in the second half of the basal coil of the cochlea. In general, as the differentiation of the cochlea begins near the base and proceeds in both directions, so the range of hearing begins with rather high notes and then spreads in both directions. This means that high notes are heard in the base and low notes in the apex, as would be expected from the structure of the tectorial membrane, which we regard as the resonator and which is narrowest at the base and broadest at the apex. I suggest that this localization applies only to notes of moderate intensity. It seems very likely that if a note be sufficiently loud, the waves set up in the cochlea may be violent enough to shake any and all portions of the tectorial membrane, organ of Corti, etc., and this would account for the general fatigue of the ear and poor reception of all ranges of pitch after exceedingly intense stimulation by any one frequency.

Now, before closing, I should like to mention an obvious objection to the work I have just reported. No doubt many of you feel that since pure tone was not used in the tests it is impossible to know what frequency was really the effective stimulus. It is certainly true that the "organette" does not produce pure tone. When I first considered this fact I regretted that we had undertaken the experiment so casually. But at that time it was too late to get more pouch young during that particular breeding season, so being unable to repeat the experiment I studied the results more closely in an effort to retrieve

something from the ashes, to find something of value in the experiment in spite of the fact that we had not used pure tone. Fortunately, this process of rationalization turned out to be quite worth while, for I found that it can be shown quite definitely that the first five overtones played no part in our experiment. The evidence is of this sort. E″ (1305 d. v.), the first note the opossums were able to hear, is the fourth overtone of middle C (259 d. v.). On the fiftieth, fifty-first and fifty-second days after birth the experimental litter responded regularly whenever this note was sounded as the fundamental, but did not respond when middle C was sounded as the fundamental. If E″ was sounding as the fourth overtone whenever middle C was sounding as the fundamental on the organette, then the fourth overtone must have been sounding too softly to be an effective stimulus, for the animals did not respond. The only possible difference between E″ sounded as a fundamental and E″ sounded as an overtone is a difference in intensity; and so the only two possible explanations of the consistent failure of this overtone to arouse a response in the opossum are (1) that the fourth overtone was not sounding at all, or (2) that, if sounding, it was below the opossum's threshold of stimulation. In either case it did not play a part in our experiment. Exactly the same sort of evidence is available with reference to C′, G′, C″, G″, and C,‴ the first, second, third, fith, and seventh overtones, respectively. This means that our results are just as dependable as if we had used pure tone, for only the fundamental tone in each case played any part in our experiment.

I understand that the purpose of this symposium is to bring together all the available facts concerning localization in the cochlea, and not to discuss theories of hearing. This, then, is the appropriate time for me to bring my report to a close. In summary, our evidence amounts to this. The receptor mechanism is an elongate structure. During development it does not differentiate simultaneously throughout its length, but one region nearer one end differentiates first and the process of differentiation spreads from this point in both directions. If function depends upon the completion of the receptor, and if there is localization of pitch along this linear structure, then it must be expected that the function of hearing does not develop simultaneously for all ranges of pitch, but that notes nearer one end of the adult range must be audible before other notes, and the range of hearing must subsequently spread in both directions. Our experiment shows that this is exactly what happens, and accordingly it supports the theory that there is localization of function in the cochlea, and that the highest notes are received near the base and the lowest notes near the apex.

IV. DISCUSSION FROM THE POINT OF VIEW OF THE PHYSICIST.

LXXXII.

By John C. Steinberg, Ph. D.,*

New York.

This symposium has been of very great interest to me because of the different viewpoints from which the subject has been approached. I would like to comment very briefly from a still different viewpoint, namely, the physical.

My first comments have to do with the question: Is there localization in the cochlea for low tones? When one listens to a moderately loud 50-cycle pure tone, for example, one hears not only the 50-cycle tone but tones of 100, 150, 200, 250, etc., cycles or tones which are harmonics of the 50-cycle tone. These harmonics are not present in the sound wave in the air but are introduced by the ear. They are called subjective harmonics. This phenomenon, which is of common occurrence in overloaded or nonlinear transmission systems, is supposed, in the case of the ear, to be due to overloading in the mechanism which transmits the sound wave from the eardrum to the inner ear.

The magnitude of these subjective harmonics is determined by means of a search tone which is introduced into the ear simultaneously with the 50-cycle tone. If a test is being made for the second harmonic (100 cycles) the search tone is given a frequency of 103 cycles. If a subjective second harmonic is present a beat note of three cycles will be heard. When the intensity of the search tone is adjusted until best beats are obtained, the intensity of the search tone will be about the same as that of the subjective harmonic. In this way the subjective harmonics produced by a 50-cycle pure tone, as shown in Fig. 1, were measured. The points on the vertical solid line (harmonic No. 1) represent levels in decibels above normal threshold of the 50-cycle fundamental tone. Corresponding points on the dotted lines show the levels above threshold of the subjective harmonics. When the 50-cycle tone is 30 to 40 db. above threshold the subjective harmonics are of about the same magnitude as the 50-cycle note. For higher levels, the harmonics exceed the fundamental in magnitude when expressed in db. above threshold. What is true of a 50-cycle note is true of higher frequency tones, although not to such a

*The Bell Telephone Laboratories.

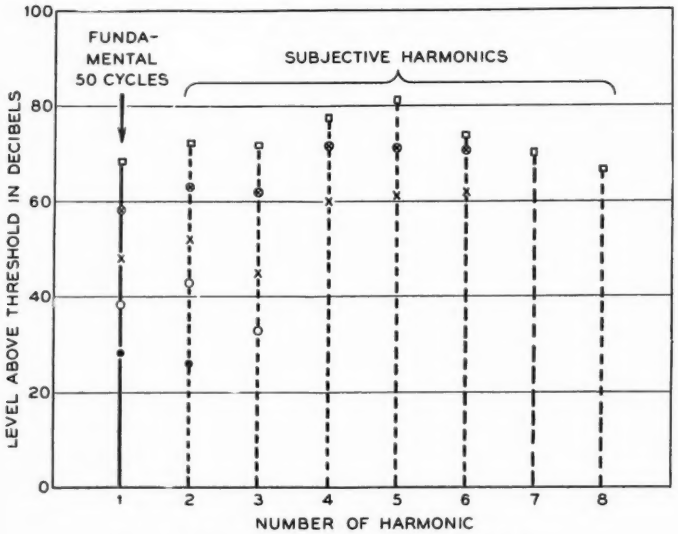

Fig. 1. Subjective harmonics of a 50-cycle tone.

marked degree. Any tone below 1000 cycles, however, will produce noticeable subjective harmonics when its level is 50 db. or more above the normal threshold.

It is evident that pure tones in the air do not mean pure tones in the ear, and that practically, low frequency tones of ordinary loudness are not localized in the cochlea owing to the presence of subjective harmonics. This does not mean that pure tones in the ear are not localized, but it does mean that such tones are very faint when of low frequency. It is probable that the harmonics of very low frequency tones are always heard before the fundamental becomes audible. When one measured hearing loss for a low frequency tone, the loss corresponding to the tone is not necessarily measured. The observed loss may be determined by one of the overtones or by the integrated effects of several overtones. For this reason, hearing losses as ordinarily measured do not necessarily show the loss in a localized area of the cochlea.

My second comment bears on the question: Is impaired hearing for the tones below 1000 cycles ever due to a cochlear or inner ear lesion? In this connection I wish to call your attention to the possibility of measuring hearing loss for sounds above the threshold rather than for sounds at the threshold, as is now done. If nerve deafness means the loss of a given number of active nerve fibers and conduc-

tive deafness means a loss or attenuation in the intensity of the sound wave, measuring the hearing loss for sounds that are 20 or more db. above the threshold will yield one audiogram for nerve deafness and a different audiogram for conductive deafness. Thus the test serves to differentiate between nerve and conductive deafness. The reason is that conductive deafness is effective at all sound intensities, whether at threshold or at levels above threshold. Nerve deafness, or the loss of a given number of active nerve fibers, is most effective for faint sounds where the number of active nerves is small. For loud sounds, there are so many active nerves that the loss of a few is unnoticed and the sounds are heard as practically normal, even though the threshold may be shifted by many decibels.

An ordinary audiogram is the difference between the normal threshold and the impaired threshold. In the same sense, an audiogram for tones that are 20 or more db. above the threshold would be the difference between the loudness as heard by the impaired and the normal ear. Such an audiogram may be obtained by balancing tones of different frequency against a 1000-cycle reference tone for equality of loudness and from the measurements of the just detectable increment of loudness increase. From recent loudness measurements with pure tones of different frequency and intensity the whole auditory sensation area has been mapped out with contour lines of equal loudness level for the normal ear.* The zero loudness level contour is the threshold of hearing, i. e., the intensity levels of pure tones of different frequency that are just audible. A 70 db. loudness level contour shows the intensity levels of tones that are equally loud to a 1000-cycle tone having an intensity level of 70 db. To illustrate the types of audiograms obtained, 70 db. audiograms have been calculated for the case of the threshold audiogram shown by curve 1, Fig. 2. This curve represents hearing loss as ordinarily understood, namely, zero is the normal threshold and curve 1 is the difference between the normal and deafened persons' threshold. For the 70 db. audiogram, the zero or normal hearing is taken as the loudness experienced by a normal person when listening to tones of 70 db. loudness level, and the audiogram is the difference between the normal and deafened persons' loudness plotted in db. If the threshold audiogram results from conductive loss only, the 70 db. audiogram is the same as the threshold audiogram and therefore is given by curve 1. If, however, the threshold audiogram is the result of a loss in active nerve fibers, the 70 db. audiogram is practically normal, as shown by curve 2.

*Fletcher, H. and Munson, W. A.: Loudness, Its Definition, Measurement and Calculation. J. Acous. Soc., October, 1933.

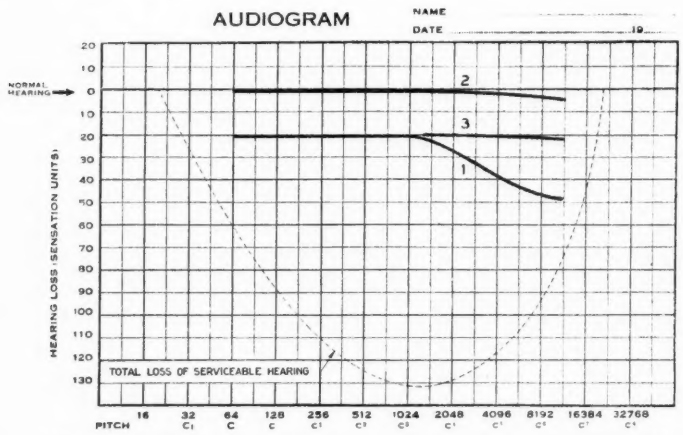

Fig. 2. Threshold and 70 db loudness level audiograms. (1) Threshold audiogram, conductive or nerve deafness. 70 db audiogram, conductive deafness. (2) 70 db audiogram, nerve deafness. (3) 70 db audiogram, part nerve and part conductive deafness.

If the threshold audiogram is the result of a 20 db. conductive loss plus a remaining loss of the nerve type, the 70 db audiogram shown by curve 3 is obtained.

Audiograms of this type obtained on individuals having impaired hearing may serve as a useful adjunct to other measurements in determining if impairment for low tones is ever due to a cochlear lesion. It may also be useful in diagnosing, particularly in cases where bone conduction tests are open to some question because of fixation of the ossicles.

V. DISCUSSION FROM THE POINT OF VIEW OF CLINICAL OBSERVATIONS.

LXXXIII.

By Max A. Goldstein, M. D.,

St. Louis.

A SUMMARY OF PERSONAL CONCLUSIONS.

Unless we can develop substantial physical and physiologic data that will reduce the efficiency or disprove the Helmholz theory and resonance philosophy as applied to the cochlea, we are as yet hardly in a position to discuss a new theory to account for the function of this organ.

Laboratory experimentation affords some definite data as to the limitations of conduction and measurement of tone frequency. It seems to be the consensus of opinion of such observers as Gasser, Erlanger, Lorente de No and Davis, that tone frequencies over 2,000 d. v. are beyond the capacity of transmission via nerve fibers.

Unless marked structural differences in the performance of the physiologic elements contained in the organ of Corti can be found, it seems illogical to measure tone frequencies below 1,000 by one standard and above 1,000 by a different standard.

It is an established fact (Lorente de No, Poljak, Lewy and Kobrak), that the ganglion of Corti is spatially projected on the primary acoustic nuclei, so that the different parts of the cochlea are connected with different nerve cells and pathways in the brain stem. This indicates that the impulses arising from the cochlea are accompanied by a local sign indicating in which specific point they were produced. In view of this fact, it seems fair to assume that differentiation of tones is mainly based on a space theory. On the other hand, it is a fact, established by Adrian, Bronk and co-workers, that the frequency of the impulses produced in a sensory nerve fiber by a suitable stimulation is proportional to the strength of the stimulus. This is true for all sense organs (tactile, muscular, visual, chemical, etc.); therefore, it is quite likely that the organ of Corti which, after all, is nothing less than a selective tactile organ, will produce in the acoustic nerve fibers trains of impulses of different frequencies, according to the intensity of the tone. This will eliminate the possibility of recognizing tone frequency by the frequency of the nerve impulses, because the increase in intensity of tone would produce a change in the frequency of the impulses.

On the other hand, although the work of Wever and Bray and of Davis and co-workers has established many important facts about the transmission of impulses through the cochlear nerve, it must be considered that those experiments were made by recording potential changes from the oval window or from the acoustic paths as a whole and that the observations made refer not to the single fibers of the nerve but rather to the whole nerve trunk.

Since it is a well established fact that lack of synchronism of the different fibers will produce interference of the potential waves, it would be illogical to conclude from these experiences that the conduction of sound through the individual fibers takes place as recorded from the whole nerve trunk.

It would be extremely desirable that methods and technic could be so perfected that the impulses conducted by the single fibers in the cochlear nerve could be definitely observed and measured.

Over thirty years ago, Bezold announced the possibility of the presence of tone islands in the organ of Corti, drawing his conclusions largely from painstaking tests made with the "contiurliche tonriehe" of tuning forks. These tone islands were determined in congenitally deaf children with residual hearing and in types of circumscribed labyrinthitis following scarlet fever or measles. Later observers have found definite evidence of the presence of partial obstruction at irregular intervals in the microscopic examination of the Corti scale where such pathologies had been caused by scarlet fever, measles or in congenital deafness with hearing residuum.

In 1920, I presented an account of improvement noticed in congenitally deaf children with residual hearing and tone islands, who, by intensive training, demonstrated marked improvement in the reception of the tone scale by actual sound tests. Even though this was long before the advent of the audiometer and actual measurement for functional tests, the evidences of such improvement were marked, but I insisted that this result was due to improvement in the central analysis of tone. The nerve cells of the brain had been educated to analyze the peripheral stimuli on the basis of information less complete than that found in the normal cochlea. At any rate, such islands of hearing seem to indicate that there is a definite projection of the tone scale in the basilar membrane.

The outstanding work carried out recently by Crowe and Guild, Poljak and co-workers, has established the existence of a projection of the high tones. We may, perhaps, entertain the hope that the continuation of that work will give a similar result for the low tones when the proper cases are found; or, if and when technical perfection has been reached in the laboratory and in the evolution of electric measuring and recording apparatus, it may yet be determined that both low and high tones of the cochlear scale within the limitation of hearing of the human ear may be proven to exist on the basis of the Helmholz theory.

LXXXIV.

By Edmund Prince Fowler, M. D.,

New York.

It is important to determine whether or not there is localization of low tones, because of the physiologic and clinical implications.

Opinions will differ largely according to the interpretation of terminology, physical background, hypothesis and clinical evidence. Clinical evidence is in its nature purely circumstantial, but even so, very important, especially if its interpretation correlates with direct evidence. To contribute something constructive from clinical evidence is difficult without a physical background because the essence of localization is physical.

TERMINOLOGY.

What is meant by "low tone"? "Low tone," like "high tone," is a comparative term. The frequency of 1000 cycles for many purposes appears to be a convenient dividing line between the low and the high tones in the octave, logarithmic or audiogram scale. Musicians distinguish 256 as middle C in the piano scale. In the arithmetical frequency scale, the lower 1000 vibrations occupy its lower twentieth. In all instances, however, it may be said that all tones below 1000 are in the lower part of the audible frequency scale. In this sense they may be thought of as "low tones." The stretch between octaves appears equal on the audiogram, but each octave contains as many frequencies as all the octaves below it. It may be significant that single nerves (other than the auditory) appear unable to transmit impulses over 500 to 1000 a second and that the sensitivity of the ear increases with frequency only up to about 1000 dv. The term "lowest tones" should be reserved for the frequencies heard below 20 dv.

What is meant by "localization" of a tone? A tone is localized in a physical sense when it activates any definite spot or region more than other spots or regions in the same apparatus or object. There are degrees of localization. Localization is greatest when the stimulus is more confined to an area which is small compared to the whole. The stimulus in the cochlea is a vibration, and it is fairly evident that localization is dependent upon frequency. In any irregularly shaped object the different frequencies will localize in different areas and distribute themselves from high to low according to the changes of dimension, and the variations in tension, weight, inertia and elasticity. The strings of a harp are often used as an illustration of the general properties of one such object, but the analogy, though useful, is far from perfect.

The basilar membrane is well situated and constructed to function as a localizing apparatus for the vibrations received by way of its lymph channels.

PHYSICAL BACKGROUND.

Reception of Vibrations by Way of the Stapes.—To visualize, in a very simple way, just what happens when sound impulses are pumped into the inner ear, draw or construct the usual schematic unrolled cochlea with windows, basilar membrane and helicotrema. Think of the basilar membrane as a mobile diaphragm (or a section of a diaphragm) separating the relatively incompressible fluids in the two scalæ. If in such an arrangement the stapes and round window membranes are absent and a steady stream of fluid is caused to flow through the cochlea by way of the oval window, the whole basilar membrane would be slightly depressed, but more markedly in its extreme upper portion because that portion is the most mobile and least resistant. There would be zero frequency, but, even so, a localization effect.

If the stapes is moved slowly and smoothly in and out at the rate of once every second there would be imparted to the fluid contents of the apparatus the frequency of one (one complete double vibration.) This (or some slower rate) being a very slow motion, it can be seen that with every push and pull of the piston the fluid (perilymph) will be freely pushed and pulled through the helicotrema, and that a mobile round window membrane will bulge and retract during each complete cycle; but there would be little disturbance of the basilar membrane and little de-equalization of the pressures on its two sides.

The exact position of the oval and round windows would not be very important. Either one or both could be differently located and still function substantially in the way indicated.

If the frequency of the pumping is slowly increased a point will be reached at which the ebb and flow of the perilymph cannot pass as freely through the helicotrema as before. Now the increased flow will have no choice but to pick one of the two paths of least resistance. One path is through the helicotrema, the other is the shunt path through the basilar membrane. If the basilar membrane were immobile the whole column of fluid would have to move through the helicotrema, and, the size of the latter remaining constant, more force would be required to move the fluid than before. But the basilar membrane is not immobile, and therefore along its whole expanse provides an alternate path for the ebb and flow. The area of greatest disturbance on the basilar membrane will be the more mobile and least resistant upper portion. In other words, the frequency may be said to be localized in the upper segment.

With increasing frequency the area of greatest disturbance will travel toward its narrow or basal end, and set up localization areas varying with frequency.

If for any reason the width or length, weight, tension, and so forth, of the vibrating structures is changed, the areas of localization will also change. For instance, suppose the upper third of the cochlea is solid bone, and that the helicotrema is moved backward to the junction of the upper and middle third of the cochlea: the basilar membrane would then be only two-thirds as long as before, and the low frequencies would not affect the former upper third of the cochlea (because of its nonexistence), but the upper part of the former middle third of the cochlea is now the upper third of our smaller cochlea. A natural interpretation founded on the resonance theory is that in order for all the frequencies to find localization on this shortened basilar membrane, the areas of localization must be crowded together; in fact, they must occupy one-third less space than formerly. In other words, the smaller cochlea would function in much the same way as the larger cochlea, although the frequency of 1000 might be placed nearer its lower extremity and all the upper and lower tone localization areas be shifted. A narrowing of the cochlea would also shift the localization areas whether it was brought about by bony growth or a dilatation of the vascular bed.

Note particularly that I am not speaking of the hearing of low tones, or of any tones, but that I am speaking only of the localization of vibrations in the cochlea (that is to say, of stimulus). This is quite a different matter from the discrimination of pitch, depending upon variations of localization in the cochlea.

Cochlear dimensions vary in skulls of different sizes and in different animals. Many animals are able to closely mimic the human voice (parrot, crow, magpie, etc.). They could not so closely mimic it unless they had discrimination for pitch. If an animal has no cochlea, or only a rudimentary one, I cannot even then conceive of a total lack of localization. Even a lump of mud will have some localization for high and for low tones because it will vibrate in different parts, differently for the different frequencies.

If the helicotrema is absent or closed (in an otherwise normal apparatus) there would be left but one avenue of escape for stapes imposed pressure, i. e., the basilar and round window membranes, in which increased movement would occur.

If the round window is absent or closed (by a growth of bone or a solid plug) there would be left no efficient avenue of escape for the stapes imposed pressures, because resistance would be equal in all parts of the cochlea (not greater in the scala vestibuli as is usual) and would impede the movements of greater amplitude, which activate the low tone localization areas. The high tone areas might be impeded but little because their amplitude of vibration is minute, and there are pathways of escape for these small changes in pressure through all the cochlear openings and channels (blood, endo- and perilymph, vessels and nerves), and also through the bone.

Increase in amplitude or in frequency of stapes movement (at low frequency) produces several similar effects. Physically, both increase pressures in the cochlea. Clinically, both give a sensation of increase in intensity and in pitch. Since these sensations occur also by bone conduction it would appear that the localization and end organ pick-up is identical for air conduction and bone conduction.

Doubling of frequencies (below 1000) has a pressure effect similar to that produced by doubling the amplitude, because the principal reactions below 1000 d. v. are elastic reactions (other factors being unchanged).

For very low frequencies there seems to be no mechanical discrimination in the sense of a change of pattern on the basilar membrane.

Reception of Vibrations by Way of the Bone.—There is no consensus of opinion regarding the mechanism of bone conduction, but discussion at this time may serve at least to stimulate the imagination. It is generally felt that bone conduction is very unreliable. It certainly does not always act as expected. The same may be said of air conduction. Bone conduction at threshold is influenced less than air conduction by masking noises. The chief value of bone conduction is to detect intra- and extra-cochlear nerve lesions. Other uses will be suggested anon. Without bone conduction diagnosis is often unreliable.

Bone conduction is influenced by variations in the location and pressure and inertia of the instrument used in making the test, and the misinterpretation of feeling for hearing. The first may be obviated by using the center of the forehead, and the others may be greatly diminished or eliminated by a firm (maximum) pressure of fork or bone conduction receiver against the head. Strong pressure acts to steady the head, to damp and to mask tactile sense in the skull

coverings, and to transmit the full power of the receiver to the skull. In the normal ear bone conduction may be varied by several experimental procedures, but if a tone is down over 20 db, I have found nothing that will increase it. Bone conduction tests are misleading if one ignores the impedance of the skull, which from one mastoid to the other is seldom if ever over 10 db. Hearing by the opposite ear must be eliminated by masking in order to obtain a true graph of the ear being tested.

In the aged, bone conduction is usually diminished, but so also is air conduction, and if definite losses are recorded for both, it will be found that bone conduction is not lower than air conduction at the same frequencies. Statements to the contrary are usually made because tuning forks are used, as in the Rinne test, and no allowance is made for the fact that, as usually employed, forks are heard only about one-half as long by bone conduction as by air conduction, and audiometrically their intensity range is seldom greater than 65 db.

The bone conduction minimum audibility line on the audiogram chart is usually used as the base line, without keeping in mind the fact that the bone conduction line is 35 to 55 db. (depending on frequency) below the air conduction base line. To avoid confusion it is advisable always to measure air conduction and bone conduction from a common base line and in the same units of measure.*

It is difficult to get away from the popular idea that vibrations are different from slow or pumping pulsations. As a matter of fact, no matter how rapid or how slow vibrations are, each one is still a pulsation, a push and a pull, a to and fro (or oscillating) movement in the media vibrating.

OVAL AND ROUND WINDOW IMPEDANCE.

When testing bone conduction the whole labyrinthine wall acts as a pump. Increased pressure compresses the cochlear contents and seeks escape through all openings, but more successfully by way of the round window. When the stapes is ankylosed and moves only as a part of the labyrinthine wall there is no escape by way of the oval window; the increased pressures are then shunted through the basilar membrane. The increased shunting is proportional to the impedance of stapes movement, and is possible only if the round window is functioning.

*Losses as much as 15 or 20 SU at single frequencies are often not dependable because many factors besides nerve lesions may cause them.

The stapes has a larger area, more inertia (because of weight) and a smaller membrane than the round window membrane. It therefore normally moves relatively much less in relation to the bony labyrinth than the latter, and normally by air conduction, in opposite phase. (One window goes in while the other goes out.) If in similar phase and equal excursion, standing waves would be set up and the result would be little or no movement of the basilar membrane. (All this is, of course, relatively speaking.)

Vibrations by way of the cranial bones cause the annular ligament and the stapes to act in very much the same way as does the round window membrane. Both windows serve to relieve pressures in the cochlea, and the release is in the same phase, but of unequal proportions. Otherwise there would be no movement of the basilar membrane.

Pressures received by way of the labyrinthine walls flow towards and away from

a. both windows if both are functioning;
b. one window if the other is not functioning;
c. neither window, if neither is functioning.

In the latter case there is no directional path for pressure release, and whatever dissipation there is would be by way of the bony walls and through the openings of vascular, lymph and nerve channels. Bone conduction would be diminished because of the impedance of all movement in the cochlea.

If only one window is mobile the movement of the basilar membrane will depend upon whether the squeeze comes more (or wholly) from the wall surrounding the scala vestibuli or the wall surrounding the scala tympani. If both scalar walls and contents were equal the squeeze from vibrations would affect both scalæ equally and there would be a movement of the basiliar membrane toward the window which gave the freer and greater release. If the scala vestibuli furnished the greater squeeze (which is not unlikely) the movement of the basilar membrane would be increased when the oval window only was impeded, and nil, or practically nil, when the round window was impeded.

If the scala tympani furnished the greater squeeze (which is improbable) the movement of the basilar membrane would be increased when the round window only was impeded, and nil when the oval window was impeded. From clinical and autopsy findings we know that bone conduction may be normal (or above) when the

oval window only is ankylosed. Therefore, it would appear that the pressures do not come more or wholly from the scala tympani wall. It follows that they must come more from the scala vestibuli wall. It is not necessary that the pressures come wholly from one scala. So long as there is a difference between the scalar pressures and a difference in the release at the two windows movement of the basilar membrane is possible, and only then.

Bone conduction will vary indirectly with the free movement balance between the two windows. However, increased impedance at the round window only does not allow of an increase in low tone bone conduction, because any increased movement imposed upon the oval window cannot compensate for the loss of motion at the round window, even though the squeeze be applied to both scalæ equally. The margin of free movement is less and the inertia more at the oval than at the round window membrane. Even if the round window is only partly impeded bone conduction will be diminished because the release by both windows will be thereby more equalized.

Increased impedance at the oval window only would allow of increased bone conduction, because of the possibility of greatly increased movement of the round window membrane. The compression of the cochlear contents from bone conduction is large compared to the displacement release from the stapes movement (relatively small volume changes occur with large stapes movement. Relatively large volume changes may occur with large round window movement.)

In massive otosclerosis (involving the round and oval windows) I have observed marked hearing losses by both air and bone conduction in the lower tones, becoming progressively less in the higher tones.

Culler has shown experimentally that strong pressure upon the round window membrane of the cat causes at a critical point a loss of response (by Wever and Bray), and that relief of pressure restores the response.

It is logical to conclude that no matter what air conduction may be, if bone conduction be normal for the low tones the round window is functioning near normal. I have never seen complete bony closure of the round window alone.

HYPOTHETICAL BACKGROUND.

Suppose upon a submerged circular membrane there is a distribution of grains of sand from center to periphery (as on Chladni's

plates), these grains would then be activated only by vibrations of the diaphragm immediately over them, and so each area would have its own grains of sand to represent its vibrations (i. e., a localization arrangement) plus the added effect of all other areas, etc.

Visualize the end organs as being activated only by the tissue immediately in touch with each. Then there would be possible a localization of stimulation on the basilar membrane, even though the windows and the endo- and perilymph altered the characteristics of vibrations as compared with a circular diaphragm.

Visualize every area of localization as a mound (it cannot be a point). Then although the center of a mound may determine the place of greatest stimulation, the whole mound determines the localization area, and a portion of the sides of the mound are concerned in, and are in fact, a part of the pattern of the stimulation. If the sensitive elements in the center of the mound are removed, the rest will still play a part in outlining the pattern. The pattern is, in fact, intact except in the center, and the sense of perception or the nervous mechanism appears to have the property of maintaining the sound picture even though part of its stimulus is missing.

If nothing else has happened, which of course is improbable, the stimulus pattern will not be as perfect as before, and to maintain it the threshold movement of the basilar membrane must be increased, but the cochlea will function fairly well and there will still be localization of the stimulation unless a sufficient area is affected to cut down the pattern beyond threshold recognition.

VERTIGO WITH CHANGE OF PRESSURE.

Think of the oval and round windows as pressure release ports not only for the cochlear fluids but also for the fluids in the vestibule and semicircular canals. Closed windows certainly impede pressure release from or communicated to the labyrinth. In some cases of markedly impaired hearing with recurring vertigo not only the deafness but also the vertigo may be accounted for by ankylosis of the stapes or closure of the round window, both of which interfere with the release of sudden pressure changes within the labyrinth. In unilateral or unbalanced lesions there would be less pressure relief in one ear than in the other, i. e., a transient unbalance of the binaural static sense while the pressure change is taking place, and none otherwise.

Clinically the hearing by air conduction and bone conduction would vary according to the type and extent of the lesions. The

vertigo would be intermittent or recurrent and transient, and preceded or accompanied by other signs of unbalance. Anything which brought about sudden intracranial pressure changes might cause the vertigo.

SUMMARY OF PHYSICAL AND HYPOTHETICAL DEDUCTIONS.

Vibrations, no matter how slow, are pulsations (to and fro movements).

Even with a steady flow (zero frequency) there is localization.

Localization is dependent upon frequency.

Localization varies with size, form and details of cochlear construction.

A cochlea of any size, any object, even a lump of mud, will show localization for low tones.

Variations of impedance in the cochlea or at its windows vary the response in movement of the basilar membrane.

Amplitude and frequency variations affect cochlear pressures and stimulation patterns, and both cause a sensation of change in intensity and in pitch.

The low tones are best suited for binaural localization of sound.

By bone conduction the whole labyrinth wall acts as a pump (ankylosed stapes moves as wall).

The oval and round windows are pressure release ports not only for the cochlea but for the static labyrinth as well. Vibrations flow to and from any mobile window.

Bone conduction varies directly with the difference in freedom of motion at the two windows.

The motion of the basilar membrane is identical for air conduction and bone conduction.

Bone conduction losses may be equal to but never convincingly greater than air conduction losses.

Bone conduction is less influenced by masking noises than air conduction.

Bone conduction, or coinciding air conduction and bone conduction graphs, are best suited for the study of low tone localization in subnormal ears.

CLINICAL BACKGROUND.

Experimental and clinical observations show that conductive mechanism lesions impede air conduction to the cochlea, but unless the round window membrane is involved they do not interfere with bone conduction. Some may, and in fact do, increase bone conduction.

From theoretical reasoning it would appear that the basilar membrane moves exactly the same amount and in the same way for air conduction as for bone conduction to obtain audibility in the normal ear at the different frequencies. Also that in the subnormal ear only nerve apparatus deficiencies will require a greater movement of the basilar membrane for minimum audibility.

These beliefs are strengthened by the following clinical observations:

1. By bone conduction and by air conduction, pitch, loudness, quality, masking, pitch discrimination, interval discrimination, binaural sense and fatigue effects, appear to be alike.

2. In the normal and in the abnormal ear (at moderate intensities) we get the same story, and this appears to be reasonable and to have an important bearing upon the physiology and pathology of the ear.

3. In pure nerve deafness, losses by AC and BC are similar. Conversely similar AC and BC losses indicate pure nerve deafness.

4. In pure conduction deafness, losses by AC and BC are dissimilar (only AC loss). Conversely dissimilar AC and BC losses (with no BC loss) indicate pure conduction deafness.

5. In mixed nerve and conduction deafness, losses by AC and BC are dissimilar, variable or uncorrelated. Conversely dissimilar losses by AC and BC indicate mixed nerve and conduction deafness.

Hearing curve forms, and losses, as between the two ears, are frequently similar for bone conduction even though the air conduction curves vary considerably.

If air conduction is progressively and markedly down, indirectly with frequency, usually bone conduction also will be markedly down, because these sloping curves are caused by nerve lesions which lower equally both air and bone conduction.

If air conduction and bone conduction do not coincide, bone conduction curves give the truer picture of cochlear function.

Bone conduction graphs and coinciding air and bone conduction graphs are best suited for the study of low tone localization in subnormal ears.

SUMMARY OF DIAGNOSTIC CRITERIA (TENTATIVE).

BC loss represents inner ear and nerve lesions, round (or combined) window lesions.

AC loss represents inner ear and nerve lesions, conduction lesions, oval window lesions, round (or combined) window lesions.

Differences between AC and BC losses represent conduction lesions, oval window lesions.

BC loss may be equal to but is never convincingly more than AC loss.

If all low tones are normal by AC, both the oval and round window membranes are freely mobile.

If all low tones are normal or above by BC, the stapes may be impeded but the round window membrane is freely mobile.

If all the low tones are down markedly, indirectly with frequency (or not heard) by bone conduction, the cause may be impeded round (or both) window movement (also possibly from nerve lesions).

CLINICAL EVIDENCE.

If low tones are not localized in the cochlea they should show some differences in perception under varying conditions as compared with the high tones, which latter are generally understood to be localized in the cochlea. They do show several outstanding differences as compared with the high tones, but using the physical, hypothetical and clinical backgrounds outlined, these very differences may be used as evidence to substantiate the contention that they are localized.

Conduction lesions confuse the picture in localization studies, because it is sometimes difficult to determine how much of a localized hearing variation is due to middle ear and how much to certain cochlear lesions heretofore described.

DIFFERENCES IN THE HEARING FOR LOW AND FOR HIGH TONES.

1. In the normal ear low tones by AC and BC are diminished in loudness by pressure upon the drum membrane, whereas high tones are unchanged or increased in loudness. This is due to impedance in

the conduction mechanism and to damping of the labyrinth walls (both affect most the large amplitude low tones).

2. In nerve deafness the low tone rate of loss with frequency is less, on the average, than in the high tones by AC and BC, and is greater for BC than for AC (unless they coincide). This is usually because in nerve deafness the low tones are usually relatively less affected and there is a coincident conduction deafness. Bone conduction is therefore nearer normal than air conduction at the low frequencies and hence the slope of the bone conduction graph is necessarily steeper—i. e., it starts higher than air conduction and ends near the same level as air conduction.

3. Marked narrow gaps are not found in the low tone areas. This is because of the relatively large spread of the low tone localization areas and the sparsity of nerve lesions confined to small areas of the spiral ganglia, or to a few nerve fibers in the upper third of the cochlea.

4. By bone conduction marked wabbles seldom occur in the low frequencies. If bone conduction does not coincide with air conduction but remains near normal the wabbles are due to obstructive lesions, not to nerve lesions.

The following physical and clinical observations are also offered as possible explanations for the lack of narrow gaps and wabbles in low tone graphs without attributing the fact to absence of localization.

(a) Localization areas on the basilar membrane (or on any membrane) increase in size (width and breadth) indirectly with frequency. There are few frequencies between the lower octaves and hence the absence of a considerable area would not remove as many, or so markedly change the vibration pattern on the basilar membrane, as in the higher frequency areas.

(b) Increased intensity of stimulation is always necessary for minimum audibility in nerve or end organ deafness. The increased intensity brings into play more nerve elements about the periphery of the larger low tone localization areas than about the periphery of the smaller high tone localization areas. In this way it may be possible to avoid much loss of pattern for audibility and discrimination for the low tones, in spite of small localized lesions on the basilar membrane or of the spiral ganglia.

5. Low tone tinnitus is seldom accompanied by deafness only near the same frequency as the tinnitus (because its cause is so often

extra-cochlear). High tone tinnitus is frequently accompanied by deafness very near the same frequency as the tinnitus (because its cause is so often intracochlear). The first is not due to a small, localized lesion; the second often is.

6. Masking curves measured in octaves are wider at low frequencies than at high. The explanation is probably as follows: A low tone always masks other tones more when they are near it in pitch. If there was no localization for low tones—that is, if the whole basilar membrane was equally stimulated by low tones, then it would seem likely that all high tones should be masked alike by the low tone, which is not the case.

7. Low tones (those below 1000) are the most useful in the binaural localization of sound. This may be because of a more favorable set-up for synchronization. The localization patterns on the basilar membrane are larger for the low tones and therefore provide broader bases for comparison. The shifts in the motion of the basilar membrane will be toward the apex of the cochlea in the ear hearing the weaker sound, and away from the apex in the ear hearing the louder sound.

These differences between the low and high tones, as revealed by hearing tests and graphs, do not lead to the conclusion that there is no localization for the low tones, but to the opinion that they are localized under different conditions. Until localized lesions in the upper third of the basilar membrane are found coincidentally with, and correlated to, the antemortem hearing losses, it is difficult to prove directly that there is a localization for low tones, but the absence of such findings is not a valid reason for believing that there is no localization even though the pick-up from the basilar membrane may be dependent on some physical phenomena other than localization.

I have endeavored to enumerate the physical and clinical evidence concerning the localization of low tones in the cochlea so as to emphasize the changes in the cochlea windows which may account for loss in low tones irrespective of nerve lesions, and which may also account for vertigo without intralabyrinthine or brain lesions. I have suggested clinical tests for the diagnosis of all such.

In closing, I wish to point out that nature seldom if ever provides definite and complicated construction with efficient physical action, without physiologic implications, and that even if localization has nothing to do with the physiology of hearing, there is nevertheless a localization of low tones in the cochlea.

The Scientific Papers of the American Bronchoscopic Society.

LXXXV

A PERFORATING FOREIGN BODY OF THE TRACHEA.*

GORDON BERRY, M. D.,

WORCESTER, MASS.

The afternoon office work was more than half done when an internist telephoned that this patient, a healthy, energetic former college football player of about fifty, had called him to his home that morning because of a mild laryngitis consequent on a slight cold. There was no fever and no chest complication, so he had given him a soothing expectorant and had told him he had better stay in the house for a day or two. Now the patient had just telephoned of some aggravation of the laryngitis and would the doctor ask me to stop in after office hours? The chronologic development follows.

I found the patient leisurely pacing the floor upstairs. Why not sit down? Easier to breathe standing up, he smilingly said. A strange answer for a mild laryngitis case. Temperature? No. In fact, feeling fine, except the dyspnea. Heart strong and color good. Nose free; no acute congestion of nose or pharynx; no evidence thus far of any acute infection or "cold." How long had he had any dyspnea? Since two o'clock, or nearly four hours. The breathing was labored and on inspiration only, at times sounding like a croup. Expiration was clear and easy; speech similarly so, with a slight hoarseness; no bronchial cough; no raised secretions or bloody expectoration.

Examination of the larynx showed congested and rounded true and false cords, but adequately open on inspiration, with symmetrical and good adduction and abduction, and no ulcer, no tumor, no membrane, no foreign body. A fairly good light was available and with the laryngoscopic mirror I could see perhaps one inch below the glottis. The tracheal wall showed a rather dark congestion similar to that of the larynx. Below this the trachea was of a uniform dark reddish color, and apparently swollen nearly shut, with what

*Read before the eighteenth annual meeting of the American Bronchoscopic Society, Toronto, June 1, 1935.

seemed to be a small opening or chink down the trachea posteriorly to the right. There was a little streak of whitish pus on the lateral wall.

The labored inspiration and free expiration suggested a valve-like obstruction. The diagnosis of a tracheal foreign body was offered but denied. None had been inhaled or swallowed. The foreign body explanation was reluctantly abandoned. Asthma had never troubled. The absence of fever or of any acute nasal or pharyngeal congestion made it hard to call it a diphtheritic or membranous cast blocking the lower trachea. The condition might soon become urgent. Should I hurry him to the hospital before contacting his family physician? He was of the thick-set and muscular type that would make a careful bronchoscopy under local anesthesia difficult; and his labored breathing made a general anesthetic hazardous. A tracheotomy seemed indicated, but I feared the obstruction went lower, possibly down into the bronchi.

As he said he had not lost any ground for the past two or three hours, I decided to watch developments for an hour. This would give me time to discuss my findings with his internist and to call in a supporting laryngologist, both of whom were temporarily out of reach by telephone. So I went home, five minutes away, to do some more telephoning, after which I advised his wife that I had reached the family physician and also the second consultant who would be there shortly, and was told that there was no aggravation in the symptoms and that her husband seemed comfortable.

Half an hour later the telephone bell rang and the patient himself, in a more natural voice, said "It is all right, doctor. I thought I was going to strangle; then with a great effort I coughed it up. It looks about like an oyster in size and shape." So I concluded that he had rid himself of an obstructing membranous cast but that more would form and he had better go to the hospital anyway, after the consultant (who was then on his way) had seen him.

The rest of the story is as surprising as the first part was alarming. The consultant arrived, examined the coughed up mass and telephoned me that it was not a membrane but a large piece of cotton. (Fig. 1.) I went right over and the internist soon joined us. Indirect examination now showed the trachea swollen but with a free lumen and what looked like a break in the left lateral wall a little over an inch below the glottis. Then we sat down to talk things over.

The history went back to a bilateral thyroid operation eleven months previously by a nationally known surgeon and at one of

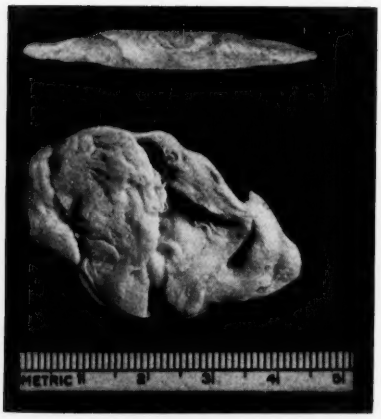

Fig. 1.

America's best hospitals. The assistant took over the operation at the last and closed the wound so well that I had not noted the scar. Prompt healing and a normal and uneventful convalescence followed. There was a little pain in the left side of the neck reaching up to the left mastoid for four days after the thyroid operation, then no more; also an occasional slight puffy swelling low in the left side of the neck, and a constant mild pulse beat in his left ear. All this was now relieved. Nine months after the operation there was a feeling of constriction or squeezing of the trachea which lasted one week, then disappeared. The present attack began with a tickle, then a cough, then hoarseness. The internist was first called that morning. The first sense of obstruction was at two in the afternoon. The foreign body was violently coughed up five hours later.

The inescapable conclusion was that a sterile piece of cotton was left in the wound. Blood stained cotton looks much like muscle tissue. It remained as a sterile irritating foreign body which worked its way to the trachea. It was already flat or flattened itself in the process and perforated between the tracheal rings. (Fig. 2.) As I read the x-ray picture it necrosed its way through one ring. Cartilage is notably prone to necrose under pressure. It was pressing its way through when I saw the swelling of the left lateral and anterior tracheal wall. Then the violent strangling effort of a powerful man ripped it through and out, and the near tragedy was over.

Convalescence was uneventful. He was pretty shaken up by the ordeal. There was a slight expectoration of pus for nine days and

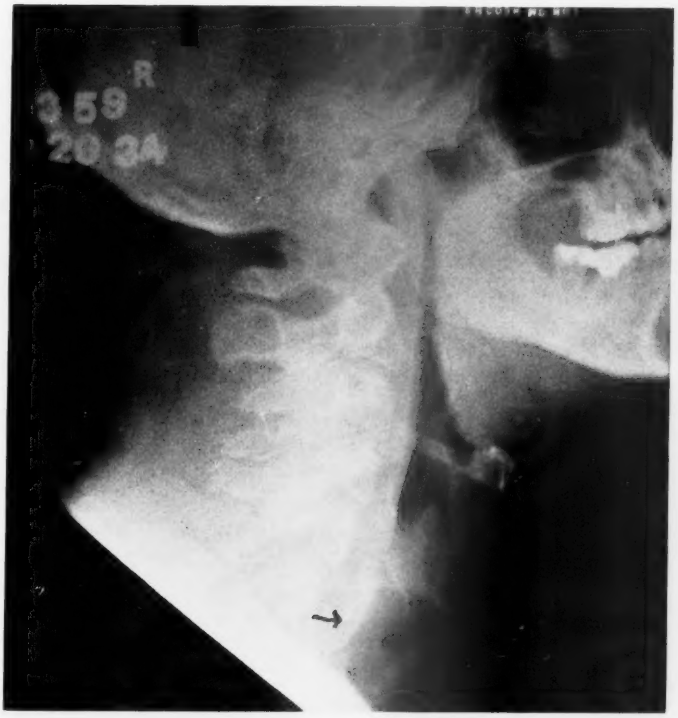

Fig. 2.

then this ceased. The laryngeal congestion quieted. The slightly elevated perforation edges in the left tracheal wall could not be seen three weeks later. There was no swelling or pain in the neck.

In retrospect, aside from the question as to how one would meet such an urgent situation, and aside from the hazard of using cotton sponges, the essential point to be emphasized by this experience is the fact that a large piece of cotton can remain in the neck without symptoms for eleven months, and then, instead of working out through the soft tissues as an abscessing process, can necrose its way quietly through the tracheal wall, to perforate into the trachea, and thus escape; the whole healing promptly and giving little discomfort or trouble with the exception of the few very anxious hours it was obstructing the tracheal lumen.

36 PLEASANT STREET.

LXXXVI.

LACTIC ACID STRICTURE OF THE ESOPHAGUS.*

CARLOS E. PITKIN, M. D.,

CLEVELAND.

Lactic acid is commonly used by pediatricians for acidification of milk in infant feeding. It was formerly used in the treatment of various forms of dyspepsia. It has been used locally as a caustic agent in tuberculous and other ulcers, also for the purpose of dissolving diphtheritic membrane. Certain contraceptives contain lactic acid and rather extensive erosions of the vaginal mucosa and cervix have occurred from its caustic action.

In a paper entitled "The Problem of Accidental Poisoning in Children," by Dr. John Aikman, read before the Pediatric Section of the American Medical Association in 1934, lactic acid was not mentioned. One case of lactic acid poisoning was found in the literature. The patient was a woman who was being treated in a hospital for gall bladder disease by duodenal lavage with 25 per cent magnesium sulphate. A nurse by mistake injected 33 per cent lactic acid through the duodenal tube. Violent abdominal pain with vomiting of bloody mucus occurred. There was a suppression of urine and hemoglobinuria. The patient collapsed and died twelve hours after the ingestion of the lactic acid. Autopsy showed a dark red duodenal mucosa and necrotic inflammation of the jejunum. Microscopic hemorrhages were present in the mucosa of the posterior wall of the stomach.

The case I wish to report is a stricture of the esophagus following accidental administration of lactic acid.

REPORT OF A CASE.

The patient, a female infant, eleven weeks old, was being fed a formula consisting of diluted evaporated milk and corn syrup acidified with lactic acid. The patient was also receiving cod liver oil. Identical bottles were used for the lactic acid and cod liver oil. A teaspoonful of lactic acid, U. S. P. 85 per cent, was given to the patient by the mother, she believing it to be cod liver oil. The infant strangled and cried. The mother at once discovered her mistake and took the infant

*Read before the eighteenth annual meeting of the American Bronchoscopic Society, Toronto, June 1, 1935.

to St. Luke's Hospital, where a gastric lavage was performed. No excoriation of the oral mucosa was noted at the time.

For three weeks following the accident the patient was unable to take food without crying, coughing and regurgitating. After beginning to swallow, there was marked difficulty in respiration, with asthmatoid wheezing, which was relieved only by regurgitation. At times cyanosis was present. The patient was then seen by Dr. Fred Rittinger, who suspected esophageal obstruction. Attempted lavage failed, as the tube met an obstruction in the esophagus. A roentgenogram with barium mixture showed a stricture in the midportion of the esophagus. Esophagoscopy without anesthesia, four and one-half weeks after the accident, revealed a concentric stricture in the midportion of the esophagus admitting a 9 Fr. dilator.

As the patient was able to swallow but little, it was thought safer to do a gastrostomy. This was performed under local anesthesia by Dr. F. G. Leonard. Seventeen days after the gastrostomy, esophagoscopy was again done, and a No. 6 ureteral catheter passed into the stomach. A roentgenogram showed the catheter coiled in the stomach. The catheter was found in the stomach by the aid of a Young urethoscope and head mirror, and brought through the gastric fistula. A silk thread was tied to the catheter and drawn through the esophagus. Retrograde dilatation with Tucker dilators was done about twice a week, starting with a 12 Fr. and stepping up to a 26 Fr. during the following six weeks. The gastrostomy was then closed.

At the time of closure, the patient was five and one-half months old and weighed ten pounds and two ounces. She was taking her feedings well. Six dilatations by blind bouginage, up to 30 Fr., were done during the next two months. Esophagoscopy at eleven months showed a normal lumen of the esophagus.

The child is now twenty-six months old, weighs thirty-two pounds, and seems to be in perfect health.

Since lactic acid is now more extensively used, accidents in the future may be prevented by labels cautioning against its use except in diluted form.

CARNEGIE MEDICAL BLDG.

REFERENCES.

Sammlung von Vergiftungsfällen, Vol. 3, 1932, pgae 71. H. Fühner.

Aikman, John: "The Problem of Accidental Poisoning in Childhood." J. A. M. A., 103:640-643 (Sept.), 1934.

LXXXVII.

REMOVAL OF MOLAR TOOTH FROM LEFT MAIN STEM BRONCHUS.

WILLIAM B. CHAMBERLIN, M. D.,

CLEVELAND.

Consultation for the removal of teeth or dental objects which have been aspirated or swallowed is not unusual in the experience of anyone who does a fair amount of endoscopic work. Jackson in 1932 had a record of 137 of such cases. These accidents usually arise in the following manner:

1. Aspiration of loose teeth by children during general anesthesia—as a rule accompanying a tonsillectomy, as this operation is usually performed at about the time of loss of the first dentition, loose or partially loose teeth frequently becoming free in the mouth when the mouth gag is inserted.

2. Aspiration of teeth during dental extraction, the tooth slipping out of the dentist's forceps. This may happen either under local or general anesthesia and occurs much more frequently than the number of reported cases might lead one to suppose.

3. Aspiration of fillings or small dental instruments during dental procedures or manipulations.

4. Swallowing of dental protheses accidentally during eating.

The following case is reported (1) on account of the size of the tooth; (2) its long sojourn in the bronchial tree; (3) its firm impaction, and (4) the extreme difficulty attending its removal.

REPORT OF A CASE.

CASE V.—A 45-year-old male had fourteen teeth extracted on the 27th of May for relief from arthritis, under gas anesthesia. Further teeth were not extracted on account of the profuse bleeding. Following the anesthesia and extraction there was a persistent cough with profuse purulent expectoration of pus and a small piece of bone. Four days later the patient consulted Dr. Finke on account of the continued cough and the persistence of his arthitis. Examination of the chest gave rales on both sides, but no other marked changes. This was attributed to the possible aspira-

---

*Read before the eighteenth annual meeting of the American Bronchoscopic Society, Toronto, June 1, 1935.

Fig. 1. Foreign body in lung.

tion of blood. An x-ray examination of the chest was advised but was refused by the patient. An x-ray on June 27th showed a large molar tooth at the beginning of the left main stem bronchus. An x-ray immediatley before the examination showed the tooth to be still in the same position.

Under local anesthesia the tooth was easily located with a 9 mm. bronchoscope, one prong presenting upward, the crown downward. The patient was extremely tractable and for one hour every possible attempt was made to move or dislodge the tooth but all to no avail. No untoward symptoms followed after the patient's return to the ward. Two days later a second attempt was made, Dr. C. E. Pitkin assisting. Alternate efforts were made by each of us with apparently little effect. A hook made from stiff wire was now inserted around one prong and firm traction made. It apparently slipped off, but in so doing seemed to move the tooth slightly from its position. Dr. Pitkin now relieved me, when on grasping the tooth firmly with the forceps it was seen to move slightly. Traction of tooth forceps and scope together was now continued and the tooth delivered into the mouth, when it slipped from the forceps but was quickly spat out by the patient. The recovery was uneventful, the patient leaving the hospital three days later.

Experience with the above case illustrates again the gross neglect of duty if x-ray examination is not made in all cases of unexplained cough.

CARNEGIE MEDICAL BLDG.

LXXXVIII.

A CASE OF INTUBATION OF THE ESOPHAGUS.*

HARRIS P. MOSHER, M. D.,

BOSTON.

The patient, H. S. S., whose case I am reporting, was a woman in the forties (47 to be exact). She was a marked hunchback from tuberculosis of the spine in childhood. She developed extreme difficulty in swallowing and gastrostomy became necessary. Barium by mouth and retrograde barium showed that the esophagus was very much deviated to the right, following the curvature of the spine, and that the middle third of the esophagus was strictured for two to three inches; its diameter was about two millimeters. All attempts to swallow a thread were unsuccessful. Under fluoroscopic control, a bougie tipped with a flexible spiral wire finder which carried a thread was passed into the stomach. The tip of the bougie and the thread were left in the stomach. After a number of trials, the thread and the metal tip were recovered and retrograde bouginage was started.

Under the date of October 23, 1934, the hospital record contains the following two paragraphs:

REPORT OF A CASE.

CASE 1.—Chief complaint: Inability to swallow anything by mouth but liquids and then only limited amounts of these.

Present illness: Last May the patient received a series of x-ray treatments for a fibroid of the uterus. Following these she had pain and paralysis in lower muscles of the back, numbness of arms and arthritis in both wrists. In October, while eating meat, she suddenly choked and was unable to swallow the bolus. Following this she had to refrain from eating meat and to chew more carefully. Otherwise food seem to "stick." The condition gradually has become more severe. She cut out various foods, and finally was reduced to a liquid diet. She lost weight rapidly.

The patient came to Baker Memorial in August, 1934, and at that time could swallow very little liquid food, and even saliva would not go down. Gastrostomy was done, and since then the patient has gained weight. Bowels are regular, appetite good and there are no symptoms from the fibroid. There is no vomiting of blood nor anything but saliva and mucus, and no cough is present.

---

*Read before the eighteenth annual meeting of the American Bronchoscopic Society, Toronto, June 1, 1935.

Fig. 1. Retouched x-ray to show the curvature of the spine. There is a feeding tube in the stomach introduced through a gastric fistula.

This patient was under my care five days short of two months.

When the string was recovered from the stomach, retrograde bouginage, first with a No. 22 and then with a No. 24 bougie, was carried out. I was surprised and disappointed that there was no improvement in the patient's ability to swallow. On this account it was decided to try intubation of the esophagus. This was done twice, first with a No. 22 flexible catheter, and later with a No. 26. With the first catheter in place the patient swallowed fluids easily. The catheter was left in seven days. Then it was thought best to remove it in order to give the patient, the physician and the esophagus a rest. The patient went home for nine days. Re-entering the hospital, retrograde bouginage up to No. 28 was carried out. This caused slight bleeding. The intubation tube was reinserted for a second time. This time a No. 26 catheter was used.

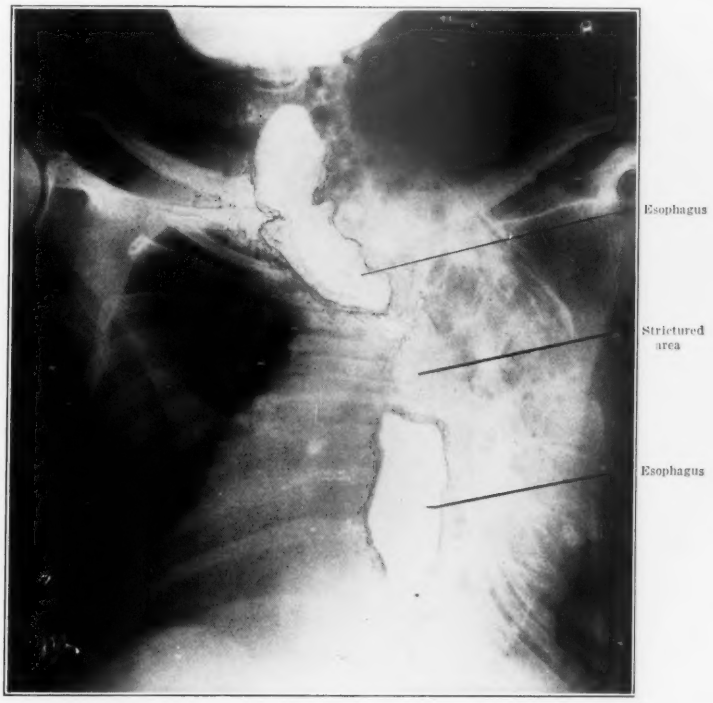

Fig. 2. Retouched x-ray showing the upper and lower portions of the esophagus filled with barium. The upper part was filled from the mouth, the lower from the stomach.

During the period between the first and second intubation, that is, two days after she returned to her home, she developed a tickling sensation in her throat and a cough. The sputum was at first yellow and then colorless and frothy. She had no chest pain. After the beginning of the cough she took nothing by mouth.

On her re-entry, as was stated above, the esophagus was intubed with a No. 26 catheter. She complained that the tube was too high. Therefore, under the guidance of the fluoroscope, the tube was lowered. From now on, the cough became more and more troublesome. It was paroxysmal and was most distressing. Four days later the tube was removed. During this time the patient had a temperature between 100 and 101.

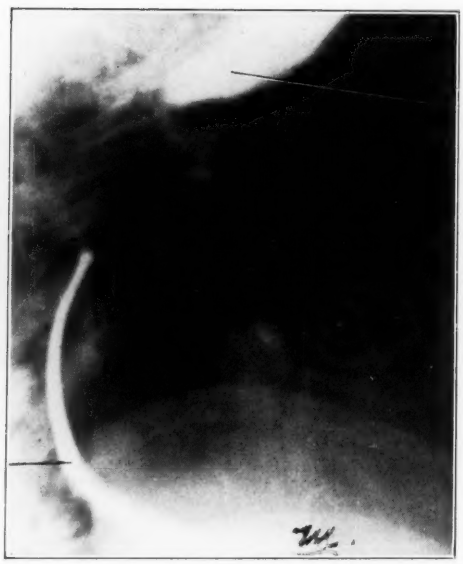

Fig. 3. X-ray showing the upper part of the esophagus filled with barium. A bougie tipped with a spiral wire finder has been introduced into the stomach. The extent of the stricture is clearly shown.

Two days after the removal of the tube, and six days after her re-entry to the hospital, the patient complained of feeling ill. She looked very ill. Naturally, I thought I was dealing with a case of mediastinitis, but the x-rays were negative. A day later, that is, on the sixth day after her re-entry to the hospital, she died a respiratory death—that is, she became cyanotic, her respirations were very much lowered, and the chest filled up with fluid.

At autopsy the esophagus was cut free just below the larynx. It was opened from behind, revealing at the top 3 cm. of normal esophagus. Below this there was a thickened indurated area 7 cm. long. There was considerable peri-esophagal reaction, resulting in rather heavy fibrosis with an abnormally dense attachment to the aorta and the trachea. The induration was abruptly circumscribed. In the middle of the thickened area there was an erosion of the mucosa 2 to 3 cm. in extent. In the middle of this area, and exactly opposite the bifurcation of the trachea, there was a fistula from the trachea to the esophagus which admitted a small probe. The total

Fig. 4. Retouched x-ray. The plate shows the successful introduction of the spiral wire tipped bougie through the strictured area and into the stomach. The lower bougie was placed in the stomach through the gastric fistula as a guide. When the two bougies crossed it proved that the upper bougie was in the stomach.

length of the thoracic esophagus was not more than 6 to 8 cm. About 8 cm. of the stomach was drawn into the thoracic cavity through the hiatus of the diaphragm.

COMMENT.

Under the heading "Comment" I have the following observations to make: The first is put in the form of a question, namely, "Did the x-ray treatment of the uterus for fibroid have anything to do with the shutting down of the stricture of the esophagus?" The patient was so deformed that the esophagus must have received some of the radiation, and the results of the x-ray treatment, according to the record, were very seevre. I cannot recall a stricture of the esophagus following tuberculosis of the spine, so something unusual happened. Dr. Holmes, the head of the x-ray department at the Massachusetts General Hospital, does not think that the treatment could have had any effect on the esophagus. Dr. MacMillan, the roentgenologist at the Infirmary, thinks that there is such a possibility. The question, of course, is almost purely an academic one.

The first practical question in dealing with the case was whether or not the esophagus was glued to the vertebral column, because if

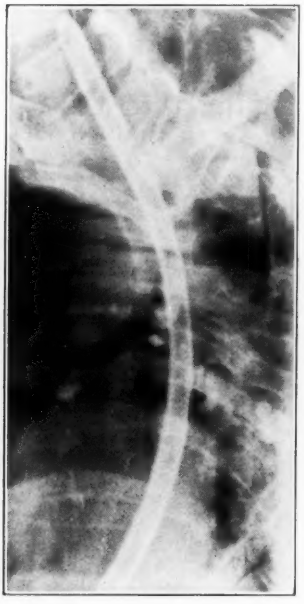

Fig. 5. X-ray showing the intubation tube in place in the esophagus.

it was it would probably be hard for any instrument to get by the marked bend. However, on exposing the upper end of the strictured area with the esophagoscope and by shifting the shaft of the tube from the left side of the mouth to the right, the esophagus was found to be movable so that the bend could be obliterated and it was possible to get a straight shot with a bougie with a spiral wire flexible tip. At the second trial under ether anesthesia and under the guidance of the fluoroscope the bougie was carried into the stomach. A thread had been attached to the tip of the bougie. When the bougie was in the stomach an attempt was made to grasp the end of the finder and bring it out the gastric fistula. As we had only a single plane fluoroscope at the time it proved to be very hard to grasp the metal tip. This was finally done, however, but the grasp was too far from the end of the finder, and the tip of the bougie with the string attached could not be brought out the fistula. It was decided, therefore, to unscrew the finder from the bougie and leave it in the stomach, and to make another attempt to get the string later. In connection with this attempt to find the metal tip with the single

plane fluoroscope I should like to add that we now have a double plane fluoroscope and in a recent case where the bougie was carried by sight into the stomach, as in this case, the spiral tip was easily seized and brought out the gastric fistula. A thread was then tied to the finder and the bougie was withdrawn, bringing, of course, the string out of the patient's mouth. The double plane fluoroscope showed that the finder was on a much deeper plane than one would expect. It was very easy to get in line with it vertically, but it was only the side view which gave the actual depth which in this case was almost two inches.

Returning to the case which is the subject of this paper, the string was finally secured by Dr. Fred, who used a wire with the end bent in the form of a hook. By fishing deep into the stomach and well to the left he was successful in withdrawing the string. The next point of importance which I wish to speak of is the fact that a very severe cough developed after the second intubation, the significance of which was not realized. It was extremely harassing and incessant, and should, I think, have made me suspicious that there was an opening between the trachea and the esophagus.

This is the second time that I have tried intubation of the esophagus. The first was years ago, when I intubed a case of fibrosis of the lower end of the esophagus, hoping thereby to increase the esophageal lumen. The patient had an extreme double twist of the esophagus. I treated this patient long before the days of the fluoroscopic examination of the esophagus and before the use of the diagnostic bag. The intubation tube was left in three days, but there was quite a lot of bleeding from time to time so that I did not dare to prolong the intubation beyond this time. The second case of intubation, the one I am reporting today, makes me wonder whether intubation, although it was very successful in enabling the patient to take nourishment, is not too dangerous to become of general use. I am wondering also why the spiral wire tube introduced by Trotter for intubation of carcinomatous strictures has not given more trouble.

Another point in connection with this case is that after we got the string through the esophagus, and after retrograde bouginage, there was no increase in the ability of the patient to swallow; also the fact that she swallowed well through the tube, but when the tube was taken out to give her a rest, the ability to swallow lasted only a few days.

To sum up: The esophagus, which was markedly bent following an old tuberculosis of the spine, was found to be movable and could be brought into a straight line for the passage of bougies. Fluoroscopic bouginage of the esophagus with a bougie tipped with a spiral wire finder was successful in reaching the stomach in two trials. A biplane fluoroscope is essential for quick recovery of the spiral wire tip from the stomach. The thread can be attached to the bougie and carried into the stomach with it, or the thread can be attached to the spiral wire finder after it has been brought to the surface through the gastric fistula. Owing to the curvature of the spine in this patient the intubation tube did not lie on a flat bed and the pressure caused by the tube might have been increased by this fact. Infection in the chest is one cause of a short esophagus. In a similar case I should persist with retrograde bouginage rather than intube.

828 Beacon St.

LXXXIX.

POSTPNEUMONIC ATELECTASIS COMPLICATING POSTPNEUMONIC EMPYEMA.*

ETHAN FLAGG BUTLER, M. D.,

ELMIRA, N. Y.

The occasional occurrence of postpneumonic atelectasis was reported by Peppard[1] in 1927. The coincident occurrence of postpneumonic atelectasis and postpneumonic empyema has been reported by myself on two previous occasions.[2,3] Under such conditions, the atelectasis, unless relieved, predisposes to chronicity on the part of the empyema. Heuer[4] lists "non-expansion of the lung following fibrosis and collapse" as one of the causes of chronic empyema. A new significance attaches to that statement when one realizes that the pulmonary fibrosis observed in the chronic empyema may not have been present during the acute stage, but may have slowly formed within an unexpanded atelectatic lobe. If the atelectasis had been relieved and the re-expansion of such a lobe had been accomplished before fibrosis had actually occurred, chronicity might have been avoided. The previously reported cases have all been carefully followed. Neither fibrosis nor bronchiectasis has occurred in any of them.

Inasmuch as a full discussion of this coincident relationship of atelectasis and empyema can be found in one of the prior articles,[3] in which four such cases were reported, the present communication will be limited to the presentation of a fifth case and a more detailed consideration of the rôle of bronchoscopy in diagnosing and treating the atelectasis.

CASE HISTORY.

The patient, EFB No. 968, was a white man, lawyer, 56½ years old. When first seen on April 24, 1934, he had been sick for nearly a month with lobar pneumonia and a left postpneumonic empyema. For ten days there had been positive x-ray evidence of the empyema. The pus was in an atypical position, lying in the anterior median por-

*Read before the eighteenth annual meeting of the American Bronchoscopic Society, Toronto, June 1, 1935.

From the Chest Clinic, the Arnot-Ogden Memorial Hospital, Elmira, N. Y.

tion of the left pleural cavity, displacing the heart far to the right and causing such extreme dyspnea that an oxygen tent was necessary. In retrospect, it is fair to assume that this empyema had originated in the left interlobar sulcus, and had thence dissected anteriorly upward toward the apex and downward between the lower lobe and the pericardium. As a result, the upper lobe had been crowded upward and backward, the lower lobe downward and backward.

On April 24, 1934, aspiration through the fourth interspace, just lateral to the left nipple, yielded pus and immediately a simple intercostal thoracotomy was performed. For a week longer the patient remained desperately sick with temperature fluctuating between 103.2 and 98.8. The oxygen tent was continued. On May 1st a secondary thoracotomy with resection was done under procain anesthesia so as to secure dependent drainage. His convalescence, however, was very slow and his temperature remained irregular, varying from 101.8 to 98.4. Occasional transfusions were given. It was evident that, owing to the extraordinary configuration of the empyema cavity, adequate drainage had not yet been secured. With the aid of opaque media the various ramifications of the cavity were accurately mapped out, preliminary to further operative effort. On May 21st, under procain anesthesia, a portion of the left second rib was resected anteriorly, together with the entire left second costal cartilage. This afforded complete command over the interlobar pocket, the apical pocket and the broad tract leading downward past the pericardium to the lowermost wound at the level of the diaphragm. Irrigation with Dakin's solution rapidly cleansed the cavity, but its size did not appreciably diminish. In spite of additional transfusions, the temperature still ranged irregularly between 101.6 and 97.6 with considerable daily fluctuation. Thus for a second month the case dragged on without any great improvement, except that the heart gradually returned to its normal position. In the roentgenologic examinations the density of the left pulmonic shadow remained decidedly greater than normal.

Postpneumonic atelectasis was suspected, but certain factors made it advisable to postpone bronchoscopic examination. As an alternative, hyperventilation with carbon dioxid was maintained, at least twice a day, for about two weeks. No appreciable benefit resulted. Finally, on June 22nd, a bronchoscopic examination was carried out and the following observation made:

Larynx normal. Trachea normal. Right bronchial tree normal. Entire left bronchial tree, as far as could be visualized, was greatly narrowed, pale and faintly striped longitudinally. There was absolutely no characteristic appearance of bron-

chial cartilages. There was no excess of secrtions, no visible variation of caliber with the respiratory efforts. It was the typical picture of inert, practically functionless lung. It was impossible to get a clear visualization of the upper lobe branch bronchus. It was also impossible to penetrate the lower lobe branch bronchus for the usual distance.

Within a few hours after this examination the patient volunteered the information that he could breathe more freely than at any time since the onset of his sickness. The day after the examination the fluoroscopic appearance of the left chest was much clearer. Subsequent to the first bronchoscopy no temperature reading was recorded higher than 99.4 except for one reading at 100.0, after a partial secondary suture of the anterior wound, under procain anesthesia, on June 30th.

A second bronchoscopic examination was carried out on July 6th, with the following findings:

Pharynx, larynx, trachea and both main stem bronchi were normal in appearance as far as they could be visualized. There was an absolute difference in the appearance of the left bronchus on this occasion as compared with the findings previously noted two weeks ago. At this time the airways were perfectly patent and perfectly dry and free of any and all secretions.

The patient was discharged from the hospital on July 17, 1934, at which time all wounds were healed except the anterior wound at the level of rib two, which still communicated with a very small clean cavity. His convalescence, however, was rapid and eventually complete. His subsequent progress has been followed closely through April, 1935, and he has remained in all respects well.

COMMENT.

The atelectasis in this and similar cases can be fairly charged to the external pressure exerted by a pleural exudate upon a lobe or lobes still filled with pneumonic secretions. When this pressure is relieved by drainage, these lobes do not immediately re-expand, but remain practically functionless. These cases differ from the typical cases of postoperative atelectasis in that the occluding secretions are to be sought not in the main bronchus to the lobe, but rather in the smaller bronchi, the bronchioli and the alveoli. The respiratory efforts in the crippled hemithorax are not sufficient of themselves to evacuate these secretions, and therefore, unless the condition is recognized and relieved, the affected lobe or lobes remain unexpanded until finally bound down by thickened pleura. As time goes on fibrosis within the lung tissue renders re-expansion improbable or impossible.

Postpneumonic atelectasis is but one of many conditions that may accompany or complicate postpneumonic empyema. These various conditions are all described in the standard works and need not be recapitulated at this time. Whenever an empyema runs an atypical course, with continued temperature, failure of the cavity to propressively diminish in size or other unusual features, it behooves the surgeon to determine the cause. Atelectasis is not the first thing to think of. In a small percentage of cases it will be the one and only complicating condition and should be kept in mind, but not until all other possible factors, including the recognized causes of chronic empyema, have been excluded, should it be advanced as the probable explanation. Once suspected, it is a simple matter to settle definitely its presence or absence.

In typical postoperative atelectasis, the physical signs and the roentgenologic examination are sufficient to establish the diagnosis. This is not true in atelectasis associated with empyema. The characteristic shift of the mediastinum toward the affected side will be prevented by the pleural exudate. Furthermore, the physical signs of the atelectasis will be masked by those of the empyema cavity. The roentgenologic appearance may be suggestive but cannot of itself be conclusive. Other diagnostic procedures are therefore necessary. Two such procedures are available; pneumonography with an opaque medium suitable for endobronchial use and bronchoscopic examination. Pneumonography should demonstrate narrow airways lying abnormally close together. There is, however, an objection to pneumonography inasmuch as the cough mechanism for expelling the opaque medium is badly impaired. The bronchoscopic findings are characteristic and can be described as pronounced narrowing of the airways of the involved lobe or lobes, absence of the normal respiratory variations in caliber, inability to clearly visualize the bronchial cartilages, moderate edema and pallor of the bronchial mucosa and, usually, some red longitudinal striation. The airways will probably be free of thick, tenacious, occluding secretions. None were found in any of the reported cases. There are no valid objections to bronchoscopy. It may, therefore, be stated confidently that bronchoscopic examination is the diagnostic procedure of choice.

The treatment of the compression atelectasis associated with empyema need not vary from the treatment of the typical postoperative atelectasis due to bronchial occlusion. Being of longer duration, however, it will not yield to simple measures. The various therapeutic steps that suggest themselves are: expectant, watchful waiting; increased activity on the part of the patient; adrenalin; atropin or

belladonna; breathing exercises, such as "blow bottles"; forced hyperventilation by carbon dioxid; and endobronchial manipulation. Watchful waiting, once the atelectasis has been fairly suspected, is to be condemned, for delay increases the risk of an intractable chronic empyema. Increased activity on the part of the patient has accomplished nothing in any of the observed cases. No conclusive statements can be offered in regard to any drug. In the case here reported a very fair trial was made of forced hyperventilation by carbon dioxid, but the atelectasis was not relieved. In one of the previously ported cases "blow bottles" had been given a fair trial but the atelectasis persisted. In this case, as well as in two of the previously reported cases, endobronchial manipulation and aspiration produced a prompt and very dramatic improvement. This improvement was apparent in the temperature curve, the roentgenologic appearance of the affected hemithorax, the size of the empyema cavity and the subjective feelings of the patient. Just how the desired result is accomplished must remain a matter of conjecture. It may be assumed, however, that during the process of endobronchial exploration with the finer aspirating tips, some of the bronchioles are freed of their retained secretion, some of the alveoli are opened to ventilation and fort[1]with the collateral respiration described by Van Allen and Jung[5] accomplishes the re-expansion of the lobe. At all events the experiences in three of the five recorded cases justify the contention that for this condition endobronchial aspiration and manipulation is the therapeutic procedure of choice.

SUMMARY AND CONCLUSIONS.

In conclusion it can be said that about 2 per cent of all postpneumonic empyemas will be complicated by an associated postpneumonic atelectasis of one or more lobes of the lung on the affected side. This atelectasis predisposes to chronicity on the part of the empyema, and unless relieved will pave the way for pulmonary fibrosis and the type of chronic empyema that can only be cured by a mutilating thoracoplasty. Such atelectasis has been successfully relieved when recognized within the first four months of its existence. Such atelectasis should be suspected whenever a postpneumonic empyema fails to clear up within a reasonable length of time, say a month, and no other satisfactory explanation can be found. Inasmuch as bronchoscopic examination is the diagnostic procedure of choice and endobronchial aspiration and manipulation is the therapuetic procedure of choice, there is a twofold reason for advising bronchoscopic examination in all suspected cases.

370 CHURCH STREET.

REFERENCES.

1. Peppard, T. A.: Postpneumonic Atelectasis. Minn. Med., Vol. 10, 1927, p. 5.

2. Butler, E. F.: Acute Empyema with Postpneumonic Pulmonary Atelectasis Relieved by Bronchoscopy. Penn. Med. J., Vol. 32, 1928, p. 337.

3. Butler, E. F.: Postpneumonic Atelectasis as a Possible Cause of Chronic Empyema. J. of Thor. Surg., 4:580, 1934-5.

4. Heuer, G. J.: Surgery of the Thorax. Nelson Loose Leaf Living Surgery, Vol. 4, chapter V.

5. Van Allen, C. M., and Jung, T. S.: Postoperative Atelectasis and Collateral Respiration. J. of Thor. Surg., Vol. 1, 1931, p. 3.

XC.

FURTHER STUDY OF ADENOMA OF THE BRONCHUS.*

RUDOLPH KRAMER, M. D., AND

MAX L. SOM, M. D.,

NEW YORK.

In 1930, one of us (K.) reported at this society the first cases clinically and bronchoscopically diagnosed as adenoma of the bronchus.[1] About the same time, Wessler and Rabin[2] presented a comprehensive report on these tumors detailing both the clinical and pathologic findings characterizing them. Our present communication includes a number of cases which formed the basis for their earlier paper. At the last annual meeting of the American Association of Pathologists and Bacteriologists, Rabin and Moolten[3] gave the criteria for the pathologic diagnosis of bronchial adenoma and its differentiation from carcinoma. We are referring to these papers because of their important contribution to the understanding and recognition of this group of tumors.

As was emphasized in the original communication, the importance of recognizing these tumors lies in the possibility of curing what is apparently a fatal disease. Many of these cases are allowed to go for years with repeated hemoptysis, recurrent pneumonias, persistent lung suppuration and empyema. In patients presenting such symptoms the first essential is early bronchoscopy. The physician is satisfied with the diagnosis of bronchiectasis in cases of lung suppuration or with the diagnosis of tuberculosis in cases of recurrent hemoptysis. As a result, many of these patients were sent to sanitaria for the tuberculous, and after a prolonged stay left in worse condition than on entrance. In the meantime the secondary changes occurring in the lung have made difficult or impossible restitution to normal. The early removal of the bronchial tumor will enable more of the patients to recover completely from the pathologic processes in the lung and bronchi.

The second essential is the recognition of the nature of the tumor by both the bronchoscopist and the pathologist. Some of the cases

---

*Read before the eighteenth annual meeting of the American Bronchoscopic Society, Toronto, June 1, 1935.

Read at the regular annual meeting of the American Bronchoscopic Society, at Toronto, June 1, 1935.

Fig. 1. Intrabronchial adenoma obstructing right main bronchus. (Postmortem specimen, Case S. W.) *A*, Smooth pedunculated tumor occluding right main bronchus. *B*, Probe inserted into distal bronchiectatic cavity.

reported in this paper were considered to be malignancies until the pathologist and clinician learned to distinguish them from carcinoma. There are a number of reports in the literature of cured cases of malignancy of the bronchus, which we are certain, both from the clinical history and from the published microscopy, are really non-malignant adenomata of the bronchus. Our experience has been that following the recognition of the tumors appropriate bronchoscopic treatment will result in a complete removal of the growth in most cases after a short time.

Macroscopic Anatomy:

The location of adenoma has almost invariably been in a bronchus of the first or second order. On one occasion the tumor was situated above the bifurcation of the trachea.

Viewed either through the bronchoscope or at autopsy, the tumor presents a smooth polypoid appearance. The shape is modified by the lumen of the bronchus which harbors the tumor mass (Fig. 1). These neoplasms are usually globular sessile growths, but may

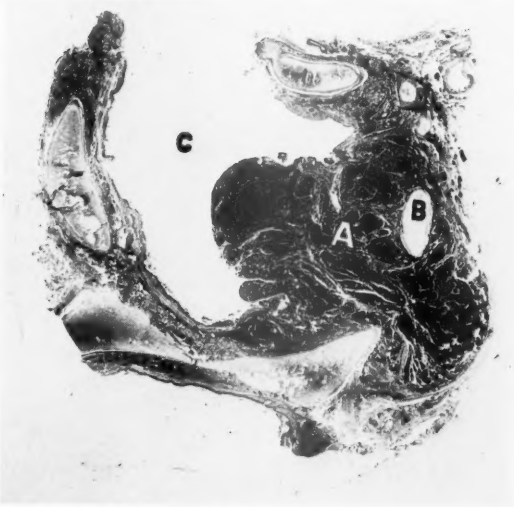

Fig. 2. Intramural adenoma of the bronchus. (Postmortem specimen, Case A. D.) *A*, Localized tumor extending into the peribronchial tissues. *B*, Bronchial cartilage surrounded by intramural adenoma. *C*, Bronchial lumen with sessile tumor partially occluding it.

be pedunculated and freely movable. The proximal bulbous end occupies a wider lumen and has a greater diameter than the distal or fixed end. The free border is directed upward because of the expulsive force of the cough. The tumor may be suddenly dislodged into the trachea and cause sudden dyspnea as happened in one of our cases.

Adenomata are nonmalignant growths which neither invade the surrounding parenchyma nor metastasize. They rarely attain large dimension, since they are confined to the limits of the bronchial lumen. Occasionally, however, their origin is within the bronchial wall proper in the vicinity of the bronchial glands between or external to the cartilages. This intramural type of growth is not limited to the boundaries of the bronchial wall and projects into the peribronchial tissues (Fig. 2). In one such case observed by us the tumor grew to the size of a grapefruit without directly infiltrating the lung or producing metastases. Metastases were not found clinically in a single instance of the six cases in this series who died. Autopsy was performed in all but one. In none of these cases was there evidence of regional or distal metastases.

In such cases as permitted of bronchoscopic removal of the growth in toto, the size could be accurately ascertained. In one case

the tumor was 1.7 cm. by 1 cm. Where the tumor was removed in stages such determination was impossible. It should be stressed that adenomata rarely come under observation until they have occluded a bronchus.

In most cases the base of the tumor is apparently attached in the submucosa and does not penetrate into the muscular wall of the bronchus. The origin of the neoplasm is probably associated with either the bronchial glands or their ducts. Such glands may ordinarily be found between the cartilages or external to them. Hence the presence of tumor tissue in these areas should not be interpreted as evidence of infiltration.

The mucosa is reflected over the substance of the tumor and lends it a smooth surface. Prominent blood vessels may be seen superficially and occasionally an ulceration covered with adherent blood clot can be noted on the mucosa. Such ulcerations in the course of a blood vessel probably represent bleeding areas (Fig. 3).

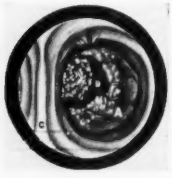

Fig. 3. Bronchoscopic appearance of adenoma. *A*, Pedunculated adenoma of right main bronchus. *B*, Infected thrombus on surface of tumor. *C*, Bifurcation of the trachea.

The neoplasms at first glance create the impression of malignancy and have previously been reported as adenocarcinoma, endothelioma and small cell carcinoma. The variegated histologic appearance of the tumor is probably due to degenerative changes of the neoplasm associated with extraneous influences as infection and physio-chemical changes due to pressure. The aforementioned influences manifest themselves on the exposed surface of the tumor and are probably the cause of the squamous cell metaplasia of the epithelial covering so frequently seen. The deeper areas of the tumor which are not influenced by degenerative phenomena present a more uniform picture. The central portion of the growth in large specimens is thus more characteristic of the tumor. Here the cells exist in solid alveolar arrangement with a delicate stroma (Fig. 4). The cells forming the alveolus are small and regular. They possess round or oval nuclei containing a finely granular chromatin but no distinct nucleolus. The shape is generally cuboidal but cylindrical cells are not uncommon (Fig. 5). The striking feature of the cells is uniformity in size, shape and staining characteristics. Mitoses are nowhere to be found.

Small bronchoscopically removed specimens often contain tissue removed from the peripheral or exposed surface of the tumor. Under such circumstances, variation in histologic appearance may be found

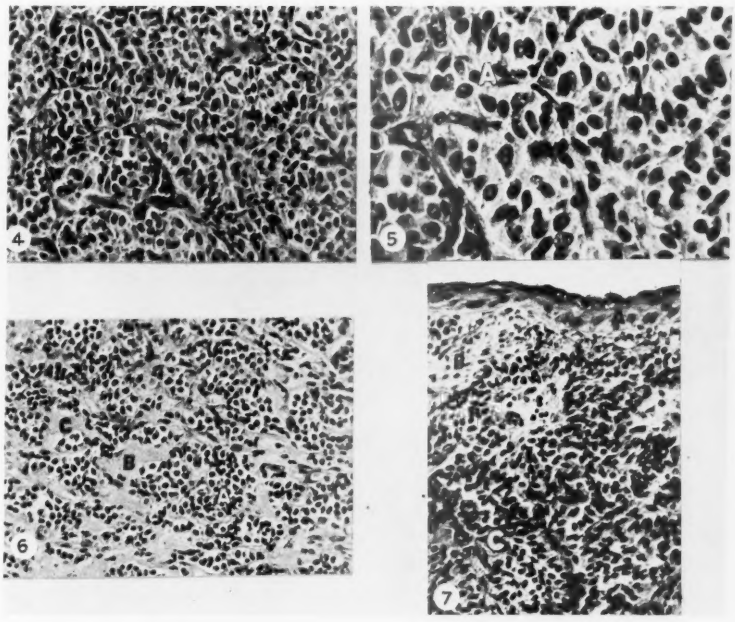

Fig. 4. Low power photomicrograph of central portion of adenoma. (Case M. S.) Solid alveolar arrangement of the cells. Uniformity in size, shape and staining characteristics of tumor cells.

Fig. 5. High power photomicrograph of Fig. 4. Central portion of adenoma. (Case M. S.) *A*, Columnar cells forming the alveolus.

Fig. 6. Low power photomicrograph of the superficial portion of tumor. (Same case M. S. as Figs. 4 and 5.) This is the usual type of biopsy. *A*, Small oval cells with dense nuclei. *B*, Hyalinized stroma surrounding islands of tumor cells. *C*, Hydropic degeneration of the cells with pyknotic nuclei.

Fig. 7. Lower power photomicrograph of adenoma showing degenerative changes superficially and solid alveolar structure more deeply. *A*, Metaplasia of the superficial epithelium. *B*, Submucosal hyaline changes in the stroma and degenerative changes in the tumor cells. *C*, Solid alveolar arrangement of the cells toward interior of the neoplasm.

which can very likely be attributed to an existing inflammation. Certain constant artifacts, such as changes produced by the squeezing action of the bronchoscopic forceps, must also be reckoned with in calculating the histologic picture. In such specimens (Fig. 6) the cells may appear small and irregularly arranged in rows or strands embedded in a stroma of variable density. The stroma may be hyalinized and enclose small sharply outlined islands of cells. Here the nuclei are small and deeply staining. The nuclei may be pyknotic and the cytoplasm clear and hydropic. In other areas atypical cells which appear to be infiltrating a hyalinized stroma may be seen. Occasionally the same slides contain areas which may be regarded as characteristic of adenoma as well as areas showing degenerative changes (Fig. 7).

The difficulty in diagnosis arises from confusion with adenocarcinoma and small cell carcinoma. The regularity in size, shape and staining quality, the tendency to alveolar formation, absence of mitoses and nuclei are valuable guides to differential diagnosis.

Incidence:

Since the introduction of endoscopic examination as a routine procedure in diseases of the chest at the Mount Sinai Hospital 332 cases of carcinoma of the lung have been bronchoscoped. During the same period 23 cases of adenoma came under observation. Thus, of a total of 355 bronchial tumors studied, 6 per cent were adenomata. The frequency of this tumor can also be estimated from the fact that among the last 118 bronchoscopic biopsies, 13, or 11 per cent, belong to this group. The latter figure is high, inasmuch as cases of parenchymal carcinoma of the lung, which do not lend themselves to bronchoscopic biopsies, are obviously excluded

Age and Sex:

Adenoma of the bronchus is more prevalent among females than males. In our series of 23 cases there were 14 or 61 per cent, of the former and 8, or 39 per cent, of the latter. The more frequent occurrence of this benign tumor in females than males is in striking contrast to the sex incidence of malignant bronchial tumors. In this group, males are more often affected than females, in the ratio of 3 to 1.

Adenoma of the bronchus may occur at any age; the youngest in our series was 13 years old, the oldest 64 years. Nevertheless, the tumor is predominately a disease of the third or fourth decade of life. Fourteen, or 61 per cent, of the total occurred between the ages

of 21 and 38 years. Again, the difference in age incidence as compared with carcinoma is apparent.

TABLE I.

		Male	Female	Total
A.	Sex	9	14	23
	Incidence	39%	61%	

		Age in Years	Number	
		13-20 years	2	
		21-30 years	8	14 or 61%
B.	Age	31-40 years	6	
	Incidence	41-50 years	5	
		54 years	1	
		64 years	1	

SYMPTOMATOLOGY.

The clinical syndrome presented by adenoma of the bronchus is similar to that of any benign bronchial neoplasm, so well described by Wessler and Rabin. The symptoms may be attributed either to

(1) irritative phenomena resulting from the tumor mass *per se*, viz., hemoptysis, cough, asthmatoid symptoms, or

(2) changes in the lung resulting from obstruction of the bronchial lumen, recurrent pneumonia, pleurisy and pyothorax, chronic pneumonitis, bronchiectasis, atelectasis, or secondary lung abscess.

In either event there may be no symptoms while the tumor is still small. It may thus exist for many years without betraying its presence.

A. Hemoptysis:

Hemoptysis is a cardinal symptom of bronchial adenoma. The bleeding is characteristic in that it starts and terminates abruptly without prolonged blood-streaking of the sputum. The hemoptysis may occur at regular intervals, especially during the menstrual cycle. Nineteen, or 83 per cent, of our series had hemoptysis at one time or another during the course of the illness. In eight of these, the hemorrhage was moderately severe in that the amount of blood lost was in excess of 100 cc. In the remaining eleven, the bleeding was scant, but sufficient to tinge the sputum bright red. In one of our cases the recurrent hemoptysis were severe enough to reduce her hemoglobin to 42 per cent. Repeated transfusions were required for maintenance of the patient's life. In eight cases the presenting symptom of illness was hemoptysis. These individuals had been in perfect health until the illness was ushered in with a sudden hemoptysis.

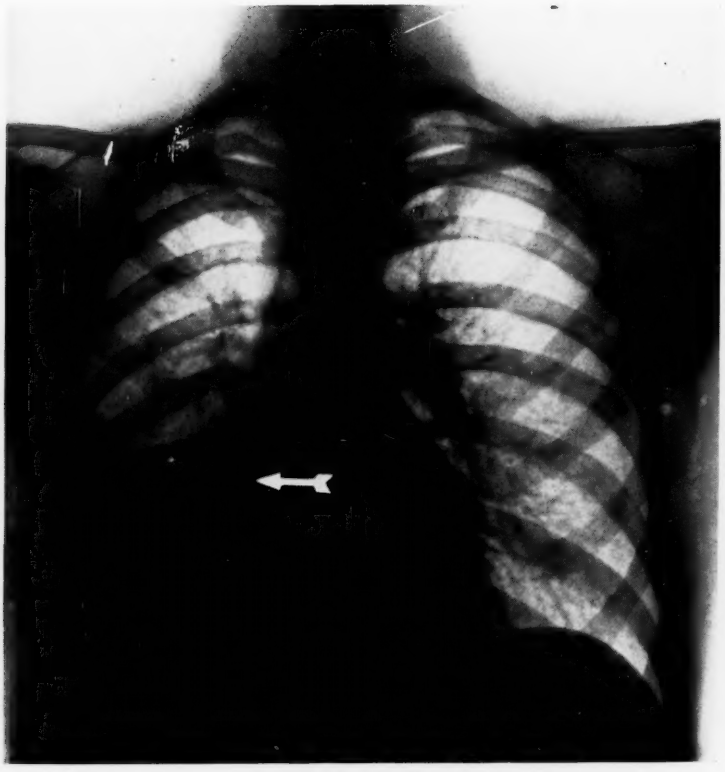

Fig. 8. Roentgenogram (Case D. B.). Atelectasis of the right lower lobe. (Before bronchoscopy.)

B. Cough:

Cough is practically a constant complaint in adenoma of the bronchus and can be attributed either to direct irritation of the bronchus by the tumor or to the infection in the lung peripheral to the obstruction. In the former case, the cough is usually dry and irritating, whereas in the latter it may be productive of purulent and at times foul sputum. In only one instance was there complete absence of cough and sputum.

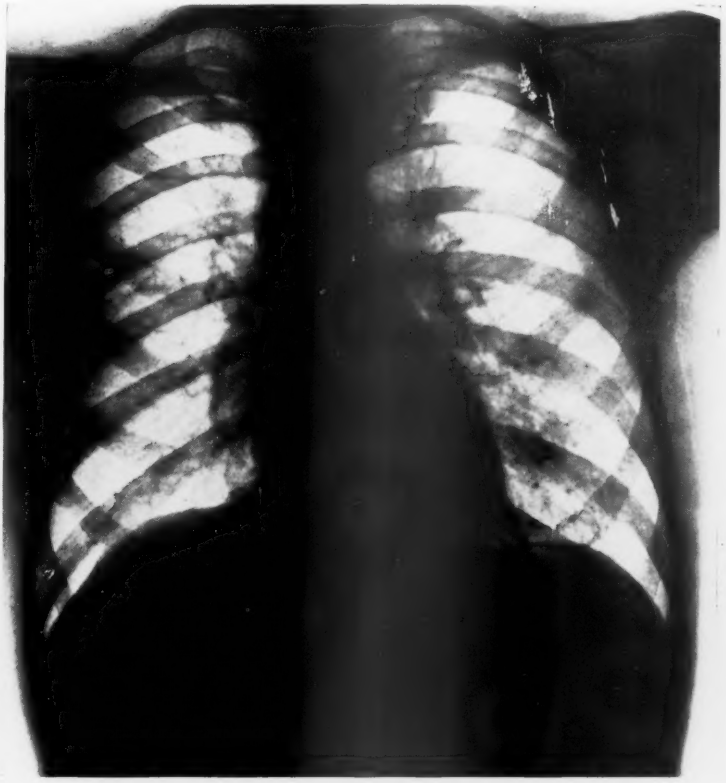

Fig. 9. Roentgenogram (Case D. B.). Expansion of the right lower lobe. (After bronchoscopic removal of tumor.)

C. Asthmatoid Symptoms:

This term is applied to the variously described sensations in the chest resulting from the partial occlusion of a bronchus with the subsequent interference of ventilation to the affected lobe. The whistling and sonorous sounds in the chest are referred to as "wheezing in the chest" or "asthmatic attacks." Eight, or 35 per cent, of our series presented this symptom complex. The sensation may be exaggerated upon reclining on the sound side or upon assuming a new posture. In seven instances the asthmatoid symptoms were the first indication of any disease in the chest. The sensation has uniformly disappeared after treatment and may cease spontaneously with complete plugging of the bronchus.

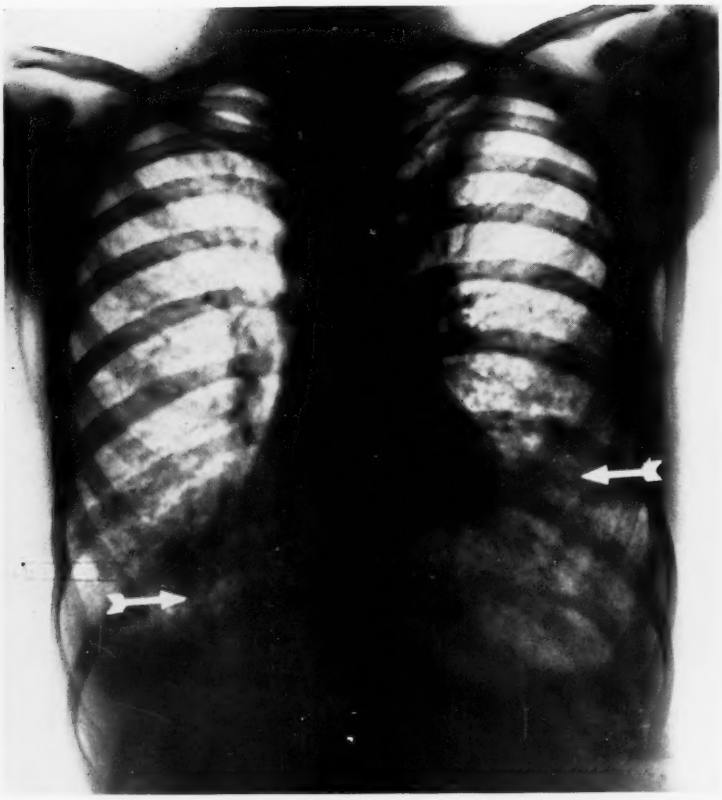

Fig. 10. Roentgenogram (Case L. R.). Bilateral bronchopneumonia. Adenoma was located just above the bifurcation of the trachea and partially obstructed both bronchi. (Before bronchoscopy.)

CHANGES IN THE LUNG FOLLOWING PARTIAL OR COMPLETE OBSTRUCTION OF THE BRONCHIAL LUMEN.

A. Recurrent Pneumonia:

A transient pneumonitis with complete restitution to normal may occur in the lung peripheral to the stenosis. Such episodes of pneumonia are likely to recur in the same lobe if the obstructive lesion persists. It may be assumed that in these instances the pneumonia was preceded by an atelectasis of the lobe. Recurrent attacks of pneumonia confined to the same lobe should arouse the suspicion of an endobronchial obstruction. Eleven, or 48 per cent, complained of such recurrent attacks as frequently as two to four times in the

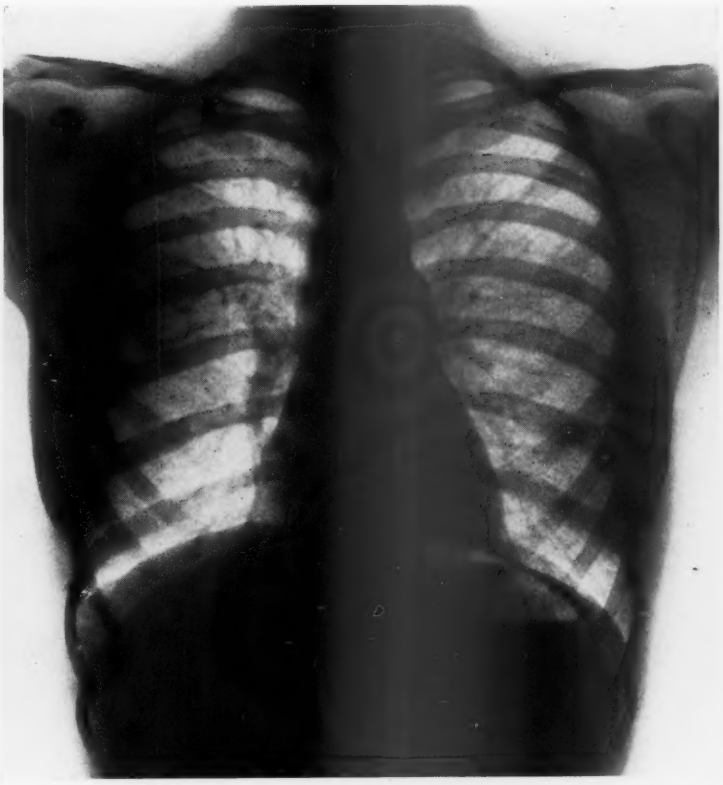

Fig. 11. Roentgenogram (Case L. R.). Complete resolution of the pneumonitis. (After bronchoscopic removal of tumor.)

same lobe. The pneumonitis has been diagnosed at times as a severe grippe.

B. Suppurative Disease of the Lung Distal to Obstruction:

The inevitable result of all cases of long standing endobronchial obstruction is suppurative bronchiectasis with chronic pneumonitis. The extent of the disease in the lung is in a large measure dependent upon the duration of the endobronchial lesion before institution of therapy. Thus in some cases where the obstruction was only of short duration complete restitution of the lung to normal was obtained after bronchoscopic removal of the growth (Figs. 8-11). On the other hand, in cases with long standing infection there was such irretrievable damage to the lung parenchyma that the relief of bron-

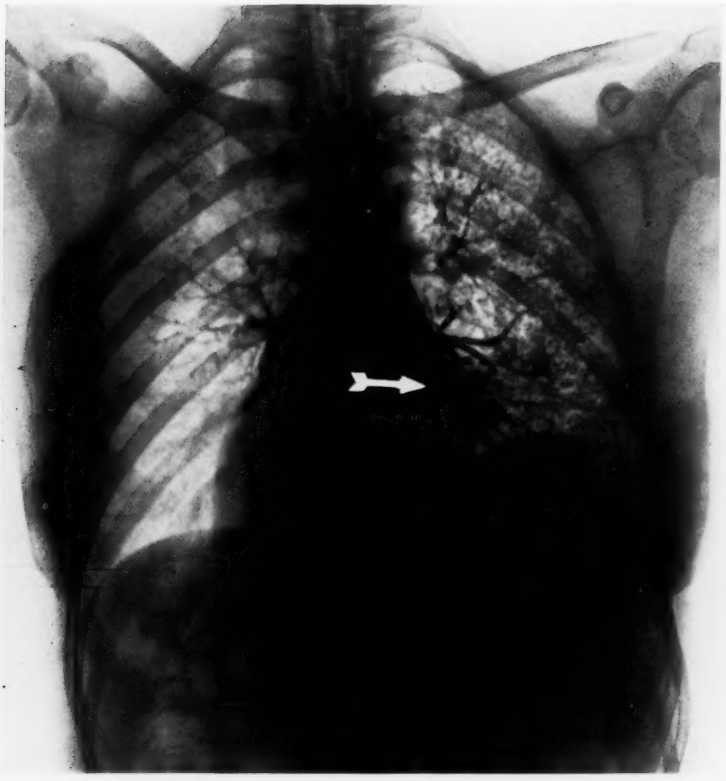

Fig. 12. Bronchography (Case M. P.). Stenosis of right lower lobe bronchus with globular bronchiectasis peripheral to the obstruction. (Case now under treatment.)

chial obstruction was not followed by cure of the disease and the patient continued to suffer from bronchiectasis. In milder cases with slight bronchial dilatation complete cure may be obtained by establishment of an adequate bronchial lumen.

Frequent attacks of pneumonitis may eventually produce a chronic pneumonitis with or without bronchiectasis. Complete stenosis of the bronchial lumen often results in atelectasis with concomitant infection or fibrosis of the lung. It would appear that an atelectatic lobe could remain uninfected for a considerable time; eventually, however, indurated pneumonitis results.

The diagnosis of suppurative bronchiectasis can best be established by roentgenographic examination with lipiodol. However, the

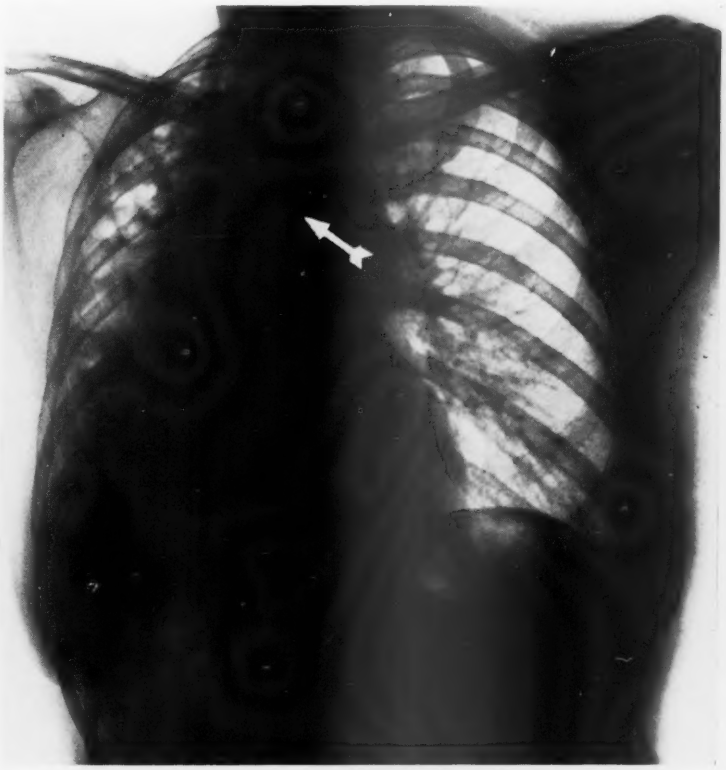

Fig. 13. Roentgenogram (Case A. J.). Displacement of the trachea by large intramural adenoma which attained the size of a grapefruit.

presence of profuse sputum, clubbing of the fingers, and abnormal x-ray findings is suggestive of its existence. In three instances where bronchography was performed the diagnosis was confirmed (Fig. 12).

Anaerobic infection of the lung, distal to the bronchial tumor, occurred six times. The sputum was foul and the clinical syndrome resembled that of primary lung abscess. However, a distinction must be drawn between primary anaerobic infection of the lung as present in lung abscess and secondary anaerobic infection distal to a tumor. Putrid bronchiectasis may similarly account for the foul smelling sputum.

Atelectasis was present in 13, or 55 per cent, of our cases. Such atelectasis was either complete or segmental, dependent upon the site

of the obstructing tumor in relation to the branch bronchi. In most cases, atelectasis was associated with bronchiectatic disease.

Empyema occurred four times in our series as a direct consequence of suppurative disease of the lung. Usually purulent infection of the pleura is a late complication in the disease.

X-Ray Findings:

The aid given by the x-ray is only indirect in that the film may show changes in the lung fields secondary to the bronchial obstruction. In one case the tumor attained such size as to produce a shadow by its own mass (Fig. 13). In another, the tumor, although small, could be visualized within the lumen of the bronchus on the roentgenographic film. This observation was substantiated at bronchoscopy. In one instance of bronchial adenoma with hemoptysis, and with no signs of bronchostenosis, the x-ray film was entirely negative.

Routine x-rays of all the cases showed the following:

TABLE II.

A. Atelectasis with or without suppuration and fibrosis	13
B. Pneumonia	3
C. Pyothorax	2
D. Chronic pneumonitis	2
E. Bronchiectasis with lipiodol	2
F. Entirely negative	1

Bronchoscopic Appearance:

Bronchoscopic examination usually reveals an occlusion of a large bronchus by a pedunculated, easily bleeding, pinkish growth covered with mucous membrane. This appearance was noted in fourteen of our cases. On three occasions the growth was referred to as "benign localized tumor." In one instance, the tumor existed for seven years and a complete stenosis of the bronchus was found. A hard, granular, pinkish growth was observed in two cases. The latter picture was found associated only with the intramural type of tumor.

TABLE III.

Pedunculated growth covered with normal mucous membrane	14
Benign localized tumor	3
Stenosis of bronchus	1
Hard granular mass	2
Bronchoscopy not done	3

Prognosis:

The prognosis varies with the time elapsing before the diagnosis is established, and depends entirely upon the removal of the tumor

Fig. 14. Bronchography (Case R. A.). Partial stenosis of the right lower lobe following complete bronchoscopic removal of the tumor. There is a residual atelectasis but no bronchiectasis. Patient is symptom-free.

before permanent damage has been done to the bronchi and lungs. Complete cure usually follows total removal of the tumor in the early phases of the disease. At a later stage, with or without bronchiectasis, the patient may remain clinically well provided the lumen is kept patent. The lung may be atelectatic and the bronchi partially or completely stenosed, yet the patient may be relatively symptom-free (four cases). The tumor itself is never directly the cause of death. The benign character of the tumor can best be judged by the duration of life since the onset of symptoms up to the time of correct diagnosis.

TABLE IV.

Duration.	No. of Cases
5-10 months	4
1-2 years	3
3-5 years	7
6-9 years	3
10-11 years	2
30 years	2
Many years	1
Undetermined	1

The pedunculated type of tumor growing into the lumen of the bronchus offers a better prognosis than the less common variety which grows in the wall of the bronchus. For complete removal of the latter type surgical excision by lobectomy is necessary.

Treatment:

The treatment of adenoma of the bronchus is the removal of the tumor through the bronchoscope and the re-establishment of the patency of the lumen. It may not be feasible to remove the entire neoplasm at once and repeated bronchoscopies may be necessary before this is accomplished. The most reliable proof that the neoplasm is completely eradicated is the absence of tumor cells in a specimen from the bronchial wall at the point of attachment of the tumor. In effecting the total removal of the tumor and the prevention of recurrence, diathermy applied to the base after removal of the main tumor has been a valuable adjuvant. Other methods of destroying the neoplastic tissue at the base or point of attachment have been employed with some success. Because of the suspicion of malignancy of the tumor, in our early cases, bronchoscopic implantation of radium into the stump of the adenoma, radium packs and external radiotherapy were used with good results. In cases where the tumor grows into the bronchial wall proper, surgical removal of the growth by thoracotomy is the only rational approach for cure.

The pulmonary complications of this disease may require surgical treatment such as drainage of an empyema or of suppurative foci in the lung.

Results:

In our series of twenty-three cases, seventeen are alive and six are dead. Of the latter, four were never treated bronchoscopically and died on their initial admission to the hospital after thoracotomy for lung suppuration. The remaining two of the fatal cases were treated by a combination of bronchoscopic removal, diathermy and radiotherapy. One of these died from hemorrhage after an illness

of thirty years' duration, and the other from lung suppuration after thirteen years of illness. Both were of the intramural type.

Of our seventeen living cases, fourteen are pursuing a normal active life after treatment. Two were untreated and continue to suffer from bronchiectatic disease without improvement. One case is now under treatment.

The fourteen adequately treated cases are living and engaged in routine activities after a duration of illness varying from one to seventeeen years, with an average of nine years since the onset of symptoms. The period of observation following the institution of treatment has varied between two months and nine years, with an average of four years.

Further analysis of these fourteen cases revealed that six are completely cured. We have designated as cured only those cases which present (1) no abnormal chest findings clinically, (2) an absence of any symptoms referable to the chest, (3) a normal x-ray film of the chest, and (4) a widely patent bronchial lumen on bronchoscopy. Three cases are symptom free. They show no clinical manifestations of disease, but still have roentgenographic or bronchoscopic evidences of either partial bronchial stenosis with atelectasis, but no infection (two cases) or dry bronchiectasis (one case). (Fig. 14.) Five cases have minimal symptoms and are fully capable of conducting a normal active existence. They exhibit none of the classical symptoms of benign bronchial tumors, viz., hemoptysis, recurrent pnuemonia, wheezing, etc. By minimal symptoms we mean the persistence of occasional slight cough with or without scant sputum. Of these five cases, three have residual bronchiectatic disease; but the infection in the lung has markedly subsided since the patency of the bronchus has been established. In each of the latter instances the disease had existed from four to seven years before bronchoscopic treatment was begun.

Comparison of the Results:

A comparison of the results obtained following the various methods of treatment reveals the fact that the method of choice is complete removal of the growth plus the application of diathermy to the base of the tumor.

In all these cases bronchoscopic removal by cutting instruments was performed first. The adjuvant measures were then applied to the stump of the tumor. It is our impression that external radiotherapy does not contribute to the eradication of the lesion. No arrest of the

progress of the growth was obtained in our two cases of intramural adenomata after external radiation. In just these cases bronchoscopic removal could not be effected and for this reason radiotherapy was employed, but it failed.

TABLE V.

COMPARATIVE RESULTS.

Procedure	No.	Results
Removal and diathermy	6	4 cures, 2 have minimal symptoms with incomplete stenosis and atelectasis.
Removal, diathermy and radiotherapy	1	Cured.
Removal and radium	2	Both symptom free, (1) with dry bronchiectasis, (1) with partial atelectasis.
Removal and radiotherapy	2	1 cure, (1) has minimal symptoms with residual bronchiectasis.
Removal, radium and radiotherapy	1	Has minimal symptoms with bronchiectasis.
Bronchoscopic removal	2	1 symptom free with incomplete stenosis, (1) has minimal symptoms with bronchiectasis.

121 EAST 60TH STREET.

BIBLIOGRAPHY.

1. Kramer, R.: Adenoma of the Bronchus. ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 39:689, 1930.

2. Wessler, H., and Rabin, C. B.: Benign Tumors of the Bronchus. Am. J. of Med. Sc., 183:164 (Feb.), 1932.

3. Rabin, C. B., and Moolten, S.: Pathology of Adenoma of the Bronchus. Ass'n. of Am. Path. and Bact., Annual Meeting, 1935.

4. Jackson, C., and Jackson, C. L.: Benign Tumors of Trachea and Bronchus. J. A. M. A., 99:1747 (Nov. 10), 1932.

5. Clerf, L. H.: Peroral Endoscopy. Arch. of Otolaryng., 17:246 (Feb.), 1933.

6. Fried, B. M.: Adenoma of Bronchial Mucous Glands. Arch. of Otolaryng., 20:375 (Sept.), 1934.

7. Kernan, J. D.: A Number of Cases of So-Called Adenoma of the Bronchi Apparently Cured by Diathermy. Section of Otolaryng., N. Y. Academy of Med., March 20, 1935.

8. Geipel, P.: Zur Kenntnis der gutartigen Bronchialtumoren. Zeitschr. f. Path., 42:516 (Jan.), 1931-32.

9. Reisner, D.: Intrabronchial Polypoid Adenoma. Arch. Surg., 16:1201 (June), 1928.

10. Myerson, M. C.: Benign Neoplasms of the Bronchus. Am. J. of Med. Sc., 176:720 (Nov.), 1928.

11. Turner, P. A.: Benign Tumors of the Bronchus with Especial Reference to Early Diagnosis. Kentucky M. J., 31:423 (Sept.), 1933.

12. Patterson, E. J.: Benign Bronchial Neoplasms. Arch. Otolaryng., 12:739 (Dec.), 1930.

XCI.

FOREIGN BODIES IN THE AIR PASSAGES: OBSERVATIONS ON COMPLICATIONS AND END RESULTS.

Louis H. Clerf, M. D.,

Philadelphia.

In compiling data concerning complications and sequelæ of cases of foreign bodies in the air passages one is confronted with many difficulties. Complications occurring while a patient is under observation in the hospital can be recorded; one can also report the immediate end results, namely, deaths and recoveries. Too often, however, the patient or his family presume that with removal of the foreign body he should be discharged promptly from the hospital instead of remaining until he has fully recovered. Accurate data on the sequelæ of aspirated foreign bodies can be secured in but a relatively small group of cases and these therefore cannot serve as a basis for final conclusions. Among the various reasons for failure to secure satisfactory follow up notes in these are the wide geographic distribution of patients, difficulty to evaluate data submitted and, most important, failure to reach patients by the commonly employed follow up methods. The economic status of a majority of patients with foreign body is not conducive towards maintaining a settled place of abode. In this group 85 per cent were ward cases.

A group of 340 consecutive cases of foreign bodies inspirated into the air passages is reviewed from the standpoint of fatalities, pre- and post-operative complications, intercurrent infections and sequela. Although no attempt is made to consider each class of foreign bodies separately and in detail, certain groups must be discussed.

Vegetal Foreign Bodies.—When considering this group I was of the opinion that peanuts were the most serious of foreign bodies from the standpoint of development of complications. This has not been borne out by my studies. Of a total of 191 foreign bodies consisting of nuts, seeds and shells, 98 were peanuts. Of these, 73 were found in patients under five years of age. The age of the youngest was 10 months. The length of sojourn varied from several hours to five and one-half months. In sixteen cases the foreign body was present from one to five and a half months. In two cases a second bron-

choscopy was performed one week following the initial foreign body removal and an additional fragment of nut removed. In two other cases repeated bronchoscopic aspirations were necessary for the treatment of pulmonary suppuration. Although it was necessary to perform tracheotomy in twelve cases there was but one fatality following bronchoscopic removal of the foreign body.

Cases of nuts, seeds and shells other than peanuts numbered 93. These included 14 beans, 11 watermelon seeds, 6 timothy heads and 16 grains of corn (maize) together with various other seeds, nuts and shells. An analysis of this group revealed that there were five fatalities and tracheotomy became necessary in 23 patients. It was also noted that three of the deaths occurred in cases of bean in the tracheobronchial tree, of which there were 14, and that in 10 it was necessary to resort to tracheotomy either as a prebronchoscopic emergency measure or following bronchoscopic removal. Of the 14 cases, 13 were from 13 months to 5 years of age, the remaining case being 11 years. Although the length of sojourn of the foreign body varied from several hours to 17 days, in all cases there were found evidences of a severe laryngotracheobronchitis.

The group of timothy head cases, six in number, is of interest. Four of the patients were under three years of age. In three the length of sojourn of the foreign body was 21 months, 9 months and 4 months, respectively. In these, extensive suppurative changes were found. In one patient, aged 8 months, tracheotomy became necessary following removal of the foreign body, which had been aspirated nine days previously.

Teeth.—These foreign bodies are commonly overlooked. There usually is contamination with the bacterial flora of the mouth. Inflammatory changes in the involved lung are common, particularly if there exists marked bronchial obstruction. Twenty-six cases are included in this series. In nine, a tooth was lost during tonsillectomy; in twelve, there was a history of dental extraction. In one, two teeth had been aspirated. Fourteen of the patients were under eleven years of age. There was one fatality following bronchoscopic removal.

Bones.—Of the sixteen cases reported, eight occurred in children from fourteen months to four years of age. It is of interest to note that bones in the bronchus commonly are overlooked. In fourteen, the sojourn of the foreign body varied from one month to seven years. Extensive suppurative changes were present in a majority of these. There were two deaths following bronchoscopic removal. One of these developed tracheobronchial diphtheria; the other died from

pulmonary suppuration and the development of extensive emphysema following tracheotomy. Tracheotomy was performed in four cases; in two of these the operation was done for obstructive dyspnea before the patients were sent to the Bronchoscopic Clinic.

Pins.—Unsuccessful attempts at removal before admission occurred more often in safety pin than in other foreign body cases. Of nine in this series one or more attempts to remove the pin were made in seven. When admitted to the Clinic all of the safety pins were in the bronchi. Fluoroscopic assistance for removal was necessary in every case.

Hardware, toys, jewelry and other objects were common foreign bodies. Many of the patients, particularly those with complete bronchial obstruction, were very ill. It was remarkable to note the prompt improvement following removal of the obstruction with re-establishment of drainage and ventilation.

Intercurrent Infectious Diseases.—Occurrence of infectious disease is not a common complication. Four cases are reported. Diphtheria occurred in one instance, a case of bone in the bronchus of a child, aged two years. The involvement was tracheobronchial and the case terminated fatally. Scarlet fever was observed in three cases, all children under three years of age. The foreign bodies present were peanut, walnut and maize, respectively. A fatal termination occurred in one.

Tracheotomy.—Tracheotomy was performed for the relief of obstructive dyspnea. In no case was this operation done for inferior or tracheotomic bronchoscopy. In many, excessive secretions and pus in the tracheobronchial tree contributed greatly to the dyspnea. When commonly employed methods, as medicated vapor and oxygen, failed to give relief, tracheotomy was performed. Intubation was not employed. In several instances a bronchoscope was introduced preliminary to the tracheotomy. The common procedure, however, consisted of orderly tracheotomy, using local anesthesia and incising several tracheal rings in the midline. In cases of excessive secretions the tracheotomy tube afforded a ready avenue for aspiration with a rubber tube. In septic laryngotracheobronchitis, as commonly occurs in cases of vegetal foreign body, considerable difficulty was experienced with crusting of secretions. On several occasions it was necessary to remove these crusts bronchoscopically through the tracheotomy fistula. The use of salt solution with or without epinephrine hydrochloride followed by mechanical aspiration, using a rubber tube through the cannula, seemed preferable. This produces less mucosal trauma with

less bleeding, and the procedure is not so distressing to the patient. It may also be repeated frequently. When crusting occurred in the smaller bronchial subdivisions the outlook usually proved hopeless.

Tracheotomy was performed in 42 patients. In eight, tracheotomy was performed before bronchoscopy; in 34, it was done after bronchoscopy. On the eight cases tracheotomized before bronchoscopy at the Clinic three had been examined bronchoscopically elsewhere and tracheotomy performed before admission; in two, tracheotomy was performed as an emergency procedure prior to admission. In the remaining three bronchoscopy had been performed before admission; tracheotomy was done as soon as the patient was admitted to the Clinic. In 34, tracheotomy became necessary for the relief of obstructive dyspnea which developed after bronchoscopy was performed at the Bronchoscopic Clinic. An unsuccessful attempt at bronchoscopic removal had been made in four before admission. Of the 42 tracheotomy operations, 35 were performed in cases of vegetal foreign bodies. Of these, 12 were done in cases of peanut in the bronchus and 23 in cases of nuts, seeds and shells other than peanut. Tracheotomy was required in four cases of bone and once each in a case of beauty pin, tooth and nail. It was of interest to note that tracheotomy was required in 10 of the 14 cases of bean in the bronchus, while it was necessary in but one of 11 cases of watermelon seed. In the latter case the watermelon seed had been present in the airway for fifteen weeks. No unusual difficulties were encountered with decannulation. Of the ten fatal cases, tracheotomy had been performed in nine. In two, the occurrence of extensive emphysema was a contributory cause of death.

Mediastinal Emphysema.—Varying degrees of emphysema of the tissues of the neck occurred in some cases following tracheotomy. In the majority, this cleared up promptly. In two cases, one, aged 19 months, with a fragment of bone in a bronchus, the other, aged 22 months, with a tooth in the bronchus, subcutaneous and mediastinal emphysema developed following tracheotomy with fatal results. It was believed that the air entered the tissues from the tracheotomy wound. In three cases, extensive emphysema of the mediastinum and subcutaneous tissues developed before bronchoscopy was performed. In one of these, a child aged two years, with a bean in the right main bronchus, there was present an atelectasis of the right lung, emphysema of the tissues of the neck and mediastinum with a slight degree of pneumothorax on the right side. Following removal of the foreign body tracheotomy was done for obstructive dyspnea. The patient made a complete recovery. It was difficult to account for the emphy-

sema, as the right lung had been atelectatic for two days. The foreign body was present for three and a half days before bronchoscopic removal. In two additional cases, reported elsewhere, the foreign bodies were peanuts. These produced marked obstructive emphysema of the involved lung. The tissue emphysema was present for several days prior to bronchoscopy. In one, physical examination of the chest could not be made, owing to the distended tissues. The emphysema subsided promptly after removal of the foreign bodies. In the case of a child, aged five years, with a peanut in the left bronchus producing complete bronchial obstruction, marked improvement followed removal of the foreign body. The obstruction recurred in several days and a second bronchoscopy was done. There was no foreign body found; a small mass of granulation tissue in the bronchus was removed. Immediately following this there developed massive emphysema of the subcutaneous tissues of the neck and chest wall. There apparently was no mediastinal involvement. This promptly cleared up and tracheotomy was not required.

Pulmonary Suppuration.—Infection of the mucosa of the trachea and bronchi with the production of purulent secretion is of common occurrence in organic foreign bodies. This usually subsides promptly with removal of the foreign body. The influence of obstruction of a bronchus on the normal drainage of bronchial secretion exerts a remarkable influence on the occurrence of pulmonary suppuration. A foreign body causing slight obstruction may remain indefinitely in a bronchus without producing harmful effects. On the other hand, in complete bronchial obstruction, the obstructive atelectasis is soon replaced by drowned lung. The irregular temperature range and other manifestations of pulmonary suppuration are characteristic. If the obstruction is of brief duration, little lung damage ensues. Prolonged obstruction, however, may lead to more serious results, namely, pulmonary abscess, bronchiectasis, pulmonary fibrosis, pyopneumothorax and bronchial stricture. The age of the patient, the character of the foreign body and its location in the tracheobronchial tree and the length of its sojourn, all exert an important bearing on the development of complications.

Pulmonary Abscess.—The occurrence of abscess of the lung as a complication of foreign body has been uncommon in my experience. The diagnosis is dependent on the roentgen findings, since it is difficult to distinguish between abscess and bronchiectasis on the physical findings alone in these cases. In one case of foreign body, a bone in the bronchus which had been aspirated about ten months previously, an abscess developed. Following removal of the bone and

repeated bronchoscopic aspirations the abscess healed. There remained, however, extensive inflammatory infiltration of the surrounding lung tissue. Later a diagnosis of bronchiectasis, corroborated by the instillation of iodized oil, was made.

Bronchiectasis.—The most common and undoubtedly the most important sequela of bronchial foreign body is bronchiectasis. I believe that bronchial obstruction of long duration is the most important factor in the etiology of bronchiectasis. Of the entire group of cases studied, 81 foreign bodies were in the air passages from one month to many years. Of these, 37 were present from one to three months, 24 from three months to one year, 11 from one to five years and 6 cases were present from five to 30 years. In three, the duration could not be ascertained. In many of these there were changes indicating extensive pulmonary suppuration.

It has been difficult to secure an adequate follow-up in many of these cases. The remarkable improvement following removal of the foreign body is often interpreted as complete recovery. A certain number, however, continue with cough and expectoration even after the foreign body has been removed. I believe that satisfactory data regarding the condition of the tracheobronchial tree can be secured only by the instillation of iodized oil for roentgen visualization. I have found bronchiectasis more often in the cases of long sojourn of bones and timothy heads in the bronchi.

There are other factors that must be considered in the development of bronchiectasis. In one patient, aged two years, a peanut had been aspirated ten days previously. There was marked obstructive emphysema of the entire left lung. Following removal of a portion of nut from the left main bronchus the emphysema cleared. There then developed a small area of exudate in the lower lobe of the left lung. One week later a small fragment of nut was removed from the lower lobe bronchus with prompt recovery of the lower lobe lesion. Three years later this patient was brought to the Clinic because of persistence of cough. The chest findings indicated that there were marked changes in the lower lobe of the left lung. Iodized oil was instilled bronchoscopically. This revealed an extensive bronchiectasis. Another patient, a child, aged five years, aspirated a tooth during tonsillectomy. The tooth was removed six days later from the right main bronchus. Subsequent bronchoscopic studies and instillation of iodized oil have shown that this patient has a bronchiectasis, although she is free from respiratory symptoms. The bacteriologic findings in the peanut case revealed pneumococcus and streptococcus

hemolyticus; in the tooth case there were found spirochetes and pneumococcus. In a study by Dr. C. J. Bucher* of the bronchoscopically removed secretions secured at the time that the foreign body was removed he observed that the pneumococcus and streptococcus were the most commonly found pathogenic organisms. The spirochete was found infrequently in contradistinction to its common occurrence in pulmonary abscess or bronchiectasis unassociated with foreign body aspiration.

Pyothorax.—This complication may occur in cases of complete bronchial obstruction with extensive suppuration or in pleural injury produced by a foreign body. It was observed in two cases. One was a case of cockleburr in the right lower lobe bronchus which had been present for approximately four months. A pyothorax developed and subsequently ruptured into a bronchus. Thoracotomy for drainage was first carried out and later the cockleburr was removed bronchoscopically. The second case, a child, aged six years, had aspirated a timothy head which had lodged in the right bronchus. A pleural effusion developed within ten days after aspiration. This became purulent and external drainage was necessary. At bronchoscopy, performed several months later, the timothy head was found in a subdivision of the right lower lobe bronchus. When word was last received concerning these cases they were both in satisfactory condition. The use of iodized oil in this type of case would probably reveal interesting changes in the bronchial tree of the involved lung.

Brain Abscess.—The presence of bronchial foreign body should not in itself influence the occurrence of brain abscess as a complication or sequela. When this does occur it is undoubtedly attributable to the pulmonary suppuration. This complication was noted in one case, a man aged 37 years, who, at the age of seven years, aspirated a staple. Cough and slight expectoration had been present as long as he could remember. The physical signs over the lung did not indicate extensive changes; on the roentgen films there was noted an increase in the pulmonary markings of both lower lobes with probably an increase in the root shadows on the right side. There was no abscess present nor was there found anything to suggest bronchiectasis. At bronchoscopy the foreign body was found in the right lower lobe bronchus with one limb penetrating the posterior bronchial wall. Removal was not difficult and the patient made an apparently satisfactory recovery. He returned two months later because of headaches. Studies indicated the presence of an intracranial lesion. At

*Personal communication.

operation an abscess was found in a frontal lobe. At postmortem there was nothing observed to account for the cerebral abscess; it was believed to be secondary to the pulmonary infection.

Deaths.—There were ten deaths in the series of 340 consecutive cases of foreign bodies in the tracheobronchial tree (2.94 per cent). A brief summary of each case follows:

Child, aged two years; fish bone lower end of trachea; sojourn five days; unsuccessful bronchoscopy before admission. Tracheotomy for dyspnea second day after bronchoscopic removal of the foreign body. Diagnosis of tracheal diphtheria based on bacteriologic findings of bronchoscopically removed secretion. Died on third day.

Child, aged three years; grain of corn (maize) in trachea; sojourn seven days. Marked dypsnea. Tracheotomy performed immediately following bronchoscopic removal of foreign body. Excessive crusting of tracheal secretion. Developed scarlet fever on second day after bronchoscopy and died at Municipal Hospital three days later.

Child, aged 19 months; bone in left main bronchus; sojourn 16 days. Tracheotomy performed on day following bronchoscopic removal of foreign body. Ten hours later developed marked subcutaneous and probably mediastinal emphysema; died within twelve hours.

Child, aged 22 months; aspirated tooth; sojourn two days. Foreign body migratory in trachea. Tracheotomy necessary two hours after bronchoscopy. In about four hours developed marked subcutaneous and mediastinal emphysema. Death in 14 hours.

Child, aged one year; almond kernel in right main bronchus; sojourn ten days. Very ill. Tracheotomy for obstructive dyspnea thirty-six hours after removal of foreign body. Death two days later from acute septic tracheobronchitis.

Child, aged 14 months; bean in the left main bronchus; sojourn two days. Complete atelectasis of left lung. Death resulted from blocking of right main bronchus by portion of bean lost at glottis at time of removal.

Child, aged 5 years; bean in left main bronchus; sojourn one day. Obstructive atelectasis of entire left lung. Tracheotomy performed for obstructive dyspnea nine hours after bronchoscopic removal of foreign body. Large quantity of secretion removed. Cough reflex inadequate and aspiration of secretion through tracheotomy

cannula was done at frequent intervals. Inflammatory process extended to smaller bronchi and obstruction could not be relieved. Death occurred two days later from septic tracheobronchitis.

Child, aged 3½ years; bean in right main bronchus; sojourn two days. One unsuccessful attempt at removal before admission. Complete atelectasis of the right lung. Marked dyspnea and dehydration on admission; tracheotomy performed immediately. Bean removed bronchoscopically. Intense inflammatory changes of mucosa of entire tracheobronchial tree. Died ten hours later.

Child, aged 1 year; peanut in right lower lobe bronchus; sojourn of foreign body five days. One unsuccessful attempt at removal before admission. Tracheotomy performed on second day following bronchoscopy. Died eleven days later from acute diffuse tracheobronchitis with extensive pneumonitis involving right lower lobe.

Child, aged 11 months; beauty pin in upper trachea; sojourn eight days. One unsuccessful attempt at removal before admission. Marked dyspnea with cyanosis present. Pin removed followed immediately by tracheotomy. Patient died suddenly twenty-six hours later. At autopsy there were found inflammatory changes of the mucosa of the airway, but the cause of death could not be determined.

Three additional deaths resulting indirectly from the foreign body aspiration are reported. One resulted from brain abscess four months after the removal of a staple from the right bronchus. This had been present for thirty years. Another resulted from extensive bronchiectasis one year following removal of a nail from the left bronchus. The nail had been present for two years. The third death resulted from pulmonary abscess and pneumonia occurring ten days after a safety pin closer, bronchoscope and safety pin had been removed. During an unsuccessful attempt at removal before admission the safety pin closer became entangled in the tissues and could not be withdrawn. As a result the bronchoscope could not be removed. The tube and forceps had been in situ for twenty-six hours, the pin for three days before admission to the Clinic. Following removal of the instruments and the safety pin, the patient, a mental case, was discharged and returned to a sanatorium.

SUMMARY.

A consecutive series of 340 cases of foreign bodies in the air passages is reviewed. Certain complications are mentioned. The frequent occurrence of obstructive dyspnea in cases of nuts, seeds and shells and the necessity for tracheotomy are discussed. Attention is

directed to the influence of prolonged bronchial obstruction on the development of pulmonary suppuration, and the relative frequency of bronchiectasis. Fatalities occurring in ten cases are briefly discussed. Immediate complications are observed more often in cases of bean in the air passages; sequela are more commonly noted in cases of timothy heads and bones in the bronchi.

1530 LOCUST STREET.

Clinical Notes and New Instruments.

XCII.

A TELESCOPIC BRONCHOSCOPE.*

LOUIS E. WOLFSON, M. D.,

AND

JACOB SCHLOSS, M. D.,

BOSTON.

Bronchoscopic instruments thus far devised have the disadvantage of not permitting a good view into the upper and middle lobe bronchi. In the belief that it was impossible to overcome this disadvantage with the open bronchoscopes now in use, the idea occurred to us that a lens system might remove this difficulty. Consequently we devised a bronchoscope, using the Jackson[1] bronchoscope as a tube and one of the telescopic attachments of the Wolf-Henning[2] esophagoscope to view the bronchial tree. The Wolf-Henning esophogoscope consists of a tube, 42 cm. in length and 7.3 mm. in diameter and two telescopic attachments. The telescope chosen for bronchoscopic examination contains a system displacing the optic axis 90 degrees. The images are in the upright position; at a distance of 15 mm. the magnifying effect is $\times$ 2. The fields are about ten times as large as the fields of the usual bronchoscopes. One cm. above the window there is a strong electric bulb. Both window and bulb are visible in the reproduced x-ray pictures.

The observations were made with the patient in the upright position. The usual bronchoscopic examination was done and secretion aspirated, and the tube with the 90 degree lens inserted through the bronchoscope. The mucous membrane was then seen as if under a magnifying lens of low power. Moreover, we were able to observe the mucous membrane of the bronchi of the upper lobes somewhat beyond the first and second bifurcations. We were also able to see the openings of the other bronchi and their secondary bifurcations. The use of the instrument caused no respiratory difficulty.

*From the Medical Clinic, service of Dr. Joseph H. Pratt and the Bronchoscopic Clinic, service of Dr. H. J. Inglis of the Boston Dispensary, Boston, Mass.

In the first patient we examined we noticed that the anatomy of the bronchial tree was different from what we anticipated. The prevailing opinion has been that there is only one opening to the upper lobe. Consequently at first we were at a loss to explain the several openings seen in the area where a single one was expected. A review of the literature on the anatomy of the bronchi disclosed monographs by Narath[3] and Ewart,[4] who have described the bronchial tree very much as we had seen it in this case and several others.

We began to use the instrument in the latter part of 1934 and with it have performed fifty bronchoscopies. The following four cases illustrate the advantages which we derived from its use.

REPORT OF CASES.

CASE 1.—J. S., who had pleurisy four or five years ago and a persistent cough since, was clinically a case of chronic bronchiectasis. Examination with the Jackson bronchoscope showed a thickened polypoid mucous membrane. With the aid of the telescopic bronchoscope we were able to see in addition numerous injected vessels in the mucous membrane of the upper part of the right and left main bronchi, and a large hemorrhagic area in the right main bronchus at the level of the opening to the middle lobe.

CASE 2.—N. E. was clinically a case of postoperative lung abscess of about two years' duration. Bronchoscopic examination (Jackson bronchoscope) showed pale thickened mucous membrane with granular areas throughout the right lower bronchus. With the new instrument, not only was the mucous membrane seen better but marked trabeculation was found at the openings of the right middle and lower lobes. This trabeculation is found at autopsy in many cases of chronic bronchiectasis, but as far as we know has never been seen in the living subject. (Fig. 1.)

CASE 3.—C. D., who has had cough and difficulty in breathing for many years. Bronchoscope examination (Jackson bronchoscope) showed merely slight dilatation of the bronchioles. The patient was very co-operative and we have consequently had artist's drawings made of the different parts of the bronchial tree. Fig. 2-4 shows pictures of different openings of bronchi in the main bronchus. Fig. 2 reveals the magnified opening of the left upper lobe and the first bifurcation of the bronchus. Secondary bifurcations are also visible. Technical difficulties make it impossible to reproduce them satisfactorily in the drawing. Fig. 3 demonstrates a secondary bifurcation in one branch of the right upper lobe bronchus. Fig. 4 gives the

Fig. 1.

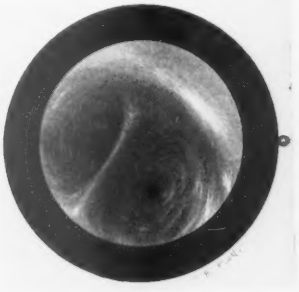

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

view into the middle lobe bronchus and shows below its opening the further course of the main bronchus.

X-ray pictures taken of the same case show the instrument in place and a catheter in the upper right lobe. Below the level of the tip of the catheter there is the atelectatic middle lobe, thus proving that the catheter runs in the intended direction. We were able to place this catheter into the bronchus under direct visual control. This was done with a special attachment to the instrument which we will describe at a later time.

CASE 4.—W. D., who had gas poisoning during the World War, has coughed and raised blood-streaked sputum ever since. Bronchoscopic examination with the Jackson bronchoscope showed a thickened, injected mucous membrane throughout. With the telescopic bronchoscope we saw in addition atrophic areas and wartlike swellings of the mucous membranes of which Fig. 5 gives some impression.

SUMMARY.

We can summarize our experience with the new instrument briefly as follows: We were able to see the mucous membrane of the bronchi as if we were using a hand lens, and consequently could not only observe finer changes but often could find abnormalities not visible with the ordinary bronchoscope. Moreover, it was possible to see further into the bronchial tree itself, which may be of great advantage in localizing pulmonary lesions, and possibly aiding in their diagnosis. It seems to us that particularly the exploration of the upper lobe bronchi in a more extensive way is a new and valuable possibility of the telescopic instrument.

25 BENNET ST.

REFERENCES.

1. Jackson, Chevalier, and Jackson, C. L.: Bronchoscopy, Esophoscopy, and Gastroscopy. Philadelphia, W. B. Saunders Company, 1934.

2. Henning, Norbert: Klin. Wschr., 11:1673, 1932.

3. Narath, Dr. Alb.: Der Bronchialbaum der Saugethiere und des Menschen. Stuttgart, 1901.

4. Ewart, Wm.: The Bronchi and Pulmonary Blood Vessels. London, 1889.

XCIII.

TIP OF THE NOSE COMPLETELY SECTIONED, AND SUTURED THREE HOURS AFTER THE ACCIDENT: CURE.

By J. N. Roy, M. D.,

Montreal.

Since about thirty years, experimental medicine has allowed surgery to make immense progress by means of tissues removed from the organism and preserved under special conditions. These tissues, of various nature, can afterwards be grafted with success, even if their extirpation dates back to a relatively distant period. Inspiring myself with these facts, I had the opportunity, a year ago, to attempt an experiment which has been fortunate and whose history is as follows:

REPORT OF A CASE.

Case 1.—On March 25, 1934, I was called in urgency at the Notre-Dame Hospital, to a child seven years of age, who had no tip of the nose. His parents then told me that the same evening, at six o'clock, he was playing with small comrades. At a certain moment he broke the glass of an automobile light with his head, and in drawing himself back he entirely severed the tip of his nose. Later, after having verified this detail, I observed that indeed the partly broken glass presented in its upper part, a pyramid form with an inferior base, and in withdrawing himself he had thrown his head backwards, a motion which had produced the injury. As the hemorrhage was considerable, the patient immediately placed his hand to his nose and came into the house. Compresses having been applied, he was afterwards taken to the hospital.

On examination, I found a transverse loss of tissue at the region of the tip of the nose, of about five centimeters in length, and by thirteen millimeters in its greatest breadth. This wound begins at the right nasolabial fold and terminates at the left fold. At this last point the cartilage of the nostril was uncovered, which produced a slight notch. There existed, moreover, a lesion of the lip and of the cheek on the left side. The hemorrhage was as yet abundant enough. I asked the father of the child if he had brought this tip

of the nose, and on his negative answer I requested him to go at once to his home and seek it.

Operation.—In order not to lose any time, I had the patient chloroformed and began without any delay the suture of the labial and cheek wound. Simultaneously an assistant made a light compression upon the nose with a piece of ordinary gauze, in order to stop the hemorrhage. Half an hour later, Mr. X. brought me the tip of the nose which was found upon a carpet in the house. It was white, and after having carefully washed it in tepid physiologic serum I placed it in the same solution, maintained at a temperature of 98.2° F., by means of the double boiler. At nine o'clock the lip and the cheek were repaired. It was then exactly three hours since the tip of the nose had been sectioned from the nasal pyramid. The hemorrhage being stopped, I made a last asepsy of the wound, and the tip of the nose well dried was carefully coapted and sutured with silk by means of small conjunctival needles. As there was no loss of cutaneous substance, I succeeded in re-establishing the anatomy of this organ. Light compressive dressing to the left nostril and to the exterior. In order to better stabilize this tip of the nose and at the same time to increase its vitality, I placed a splint in copper, fashioned for the occasion. The splint was retained by bands of adhesive tape, applied transversely to the nasal appendix. This means of protection has, indeed, rendered me great services in the past, for many varieties of rhinoplasty.

Postoperative sequelae were normal and I did the dressing of the left nostril forty-eight hours after the operation. The dressing was then daily renewed. As to the one on the exterior, I waited till March 30th to change it. At this moment there existed a dry, sanguinous layer over all the periphery of the sutured tip of the nose. This one presented at its center a reddish color which makes me hope for its vitality. (See photograph No. 1.)

In the process of time, this layer gradually eliminates itself and I had the satisfaction to see that the tip of the nose came to life again. I finished removing the sutures on April 4th. On the right side the cure is perfect, as can be seen on photograph No. 2, taken one year after the intervention.

However, the left side was less esthetic. The cartilage of this nostril, having been exposed at the time of the accident, the nutrition of the cutaneous flap has been poor. Also a loss of substance at the inferior part and a little depression in the nasolabial fold were the result.

Fig. 1. Aspect of the patient five days after the operation.

As to the lip and cheek scars, very soft, they are hardly perceptible and do not offer any interest. (See photograph No. 3.)*

This case report seems to me very instructive. It proves, indeed, that it is possible to replace a fragment of skin, separated from the organism for a few hours, and to obtain an excellent result. Carrel of the Rockefeller Institute of New York, in remarkable experiments[1] has otherwise exposed the question of active or latent life perfectly to the point, in demonstrating that a tissue, isolated from the place of its removal, can preserve its vital state, if this tissue receives artificially a nutrition which is near the normal or yet if it is kept in cold storage. According to this author, the blood plasma would be the nutritive liquid most appropriate to obtain the survivorship during a period of time relatively long. However, he is of the opinion that the cold storage offers less dangers of infection, and that it is more practical. I do not believe I should give, in this communication, the temperature to which we must have recourse for the preser-

*Wounded presented cured at the Assemblée Scientifique du Bureau Médical de l'Hôpital Notre-Dame, May 11, 1934.

Fig. 2. Aspect of the patient after the operation.

vation of the various tissues under experiment, because it would be outside of my subject.

It is admitted that there exists in a human or animal being two kinds of death—that is to say, the general death produced by the definitive stoppage of the function of the heart, and the secondary death of the elements which compose the different parts of the organism. This apparent tissular or cellular death becomes definitive and real when the cells have lost all their vital properties, following the prolonged stoppage of the nutritive and respiratory exchanges. It is then only that the microbes, coming ordinarily from the bowels, and the autolytic enzymes, act on the tissues of the organism and cause their disintegration.

On my patient the problem was very simple. The accident occurred on March 25th—that is to say, at a period of the year when the temperature is yet low enough in Montreal, and the tip of the nose had stayed in a room relatively cold before it was brought to me.

Fig. 3. Patient cured one year after the operation.

The well cleaned section had been produced by glass and all the cutaneous tissue was complete.

As to the asepsy, I must not insist more, because I was the only one responsible, to operate in the best conditions possible. However, I believe it is very important, in these cases, not to use antiseptics strongly concentrated, in order not to destroy the cellular vitality, and by the same fact to prevent the healing of the replaced fragment of skin. I know of two failures which happened to colleagues of mine, in the case of two cutaneous grafts, probably due to the use of a mercurial solution. In the presence of this sectioned tip of the nose I have thought my duty was to aseptise it as completely as possible, by the use of tepid physiologic serum—as well as for the wound of the nose—and to keep it then during one hour in this solution, at the temperature of the body by means of a double boiler.

As it had been separated from the organism during three hours, I can say that its vitality was latent during the first two hours, and

that the precautions taken during the third one had perhaps prepared or favored its return to active life.

Cure has been perfect on the right side. To the left, a small cutaneous fragment mortified itself, because it was in contact with the denuded cartilage of the nostril and consequently ill nourished. However, it will be easy later on to repair this notch and the naso-labial fold by having recourse to my personal method anteriorly described in one of my works.[2]

I attach great importance to the light pressure which must be made on the whole of the graft, in order to better re-establish its coaptation, and by the same fact to help its nutrition. Also the small apparatus in copper that I use frequently for my rhinoplasties, placed over the dressing, reaches perfectly the double aim of stabilization and protection.

To sum up, I shall say that a fragment of skin, completely separated from any part of the organism and replaced can recover its vitality, in accordance with the laboratory experience known, and which I have exposed in this work.

3434 Rue St. Hubert.

BIBLIOGRAPHY.

1. Carrel, Alexis.: The Preservation of Tissues and Its Application in Surgery. The J. A. M. A., 59:523 (Aug. 17th), 1912.

2. Roy, J. N.: Traumatic Loss of Substance of a Nostril: Rhinoplasty With a Dermo-Epidermic Graft. Arch. Oto-Laryngology, 7:601 (June), 1928.

XCIV.

HERPES ZOSTER OTICUS, WITH REPORT OF TWO CASES.*

HILL HASTINGS, M. D.,

LOS ANGELES, CAL.

I present these cases because they are rare, and because I am convinced that many of us at times have failed to make correct diagnoses.

In looking through the Transactions of the American Laryngological, Rhinological and Otological Society, I could find only one report of herpes zoster oticus and that was made by Dr. D. T. Vail twenty-nine years ago. However, there have been a few excellent papers on this subject in the medical journals.

REPORT OF CASES.

CASE 1. Mrs. I. M. L., age eighty, had been deaf for many years; she was using an electrical aid for hearing and had been treated off and on for two or three years without benefit. Her hearing test, prior to the onset of the attack which I am now reporting, showed nerve deafness in each ear. The deafness in the right ear was almost complete and there was little hearing in the left ear. She had never had any dizziness or pain.

On October 27, 1933, she returned because of a sudden onset, occurring a week previously, of pain the right ear, dizziness and a bloody discharge. There had been no respiratory infection. The dizziness at the onset of this sudden attack was so severe she had to keep to her bed. It had gradually grown less severe, and before coming to my office had almost subsided. Examination showed a blood blister on the anterior wall of the right external auditory canal that prevented a view of the fundus. On pricking this blister and wiping the bloody serum, a similar blister was found on the anterior part of the drum membrane. The posterior part of the membrane, after careful drying, was seen to be unaffected. There was no fever, no af-

*Reported at Western Section meeting of the American Laryngological, Rhinological and Otolaryngological Society, Los Angeles, January, 1935.

cial paralysis, no mastoid tenderness and no nystagmus. Two days later the right side of the chin and lip became swollen and red with small vesicles in the vicinity of the mental foramen. The occurrence of the herpes of the chin and lip on the same side as the acute ear trouble brought to my memory a paper written by J. Ramsey Hunt, the neurologist, in 1907, in the Journal of Nervous and Mental Diseases, in which he made a lengthy report on "Herpetic Inflammation of the Geniculate Ganglion: A New Syndrome and Its Complications." I found that Hunt, in 1910, in the Archives of Internal Medicine, made an exhaustive report of the symptom complex due to inflammation of the ganglia of the seventh, eighth, ninth and tenth nerves, with reports of cases where herpes of the auricle, ear canal, drum membrane, face, tongue and throat were found. Hunt thereby explained the cause of symptoms and signs in our specialty of ear, nose and throat that he said had evidently been overlooked by many of us. In further looking up references of herpes oticus (see references) I determined that this patient of mine had had an attack of inflammation of the ganglion of the fifth nerve, and that the pain and bloody serum from vesicles of the auditory canal were not due to a local inflammation of the drum membrane of the ear canal nor were the vesicles of the chin in the region of the inferior mental foramen due to local causes, but both ear and chin symptoms and signs were due to involvement of the ganglion of the fifth nerve. It was the first case in my practice that I had recognized. It is likely that a few patients I have had in my lifetime have suffered from the same cause but I was not able to see them during the vesicular stage and, therefore, did not make a correct diagnosis. It is quite likely, for the same reasons, other cases have been overlooked.

CASE 2. W. F. B., male, 77 years of age, was admitted to the Los Angeles General Hospital October 2, 1934, with the following complaint: Seven days ago he had been seized with severe pain in the right ear, lancinating in type, and dizziness. The dizziness was so severe he said he had to get down on the floor and crawl to his bed, where he stayed for several days until the dizziness became less severe. He also noticed that he was suddenly deaf in the right ear, and had severe pain in the right side of the chin and in the pre-auricular region. A vesicular eruption appeared two days later on the chin and in front of the right ear. Five days after the above symptoms and signs commenced a complete right facial paralysis developed. On the day of admission to the hospital, just seven days after the onset of the trouble, tests showed normal hearing in the left ear and almost complete loss of hearing in the right ear. The patient said when lying on

the left side he could not hear the patient in the next bed speak. The vesicles in the pre-auricular region on the right side of the jaw had ruptured and were healing. Examination of the right ear canal and drum membrane showed a large ruptured vesicle on the antero-inferior portion of the canal, and the canal was filled with a sero-sanguinous discharge. After cleaning out this discharge the drum membrane was seen to be red on the posterosuperior portion, but there was no vesicle on the drum membrane. The remaining portion of the drum membrane was only slgihtly inflamed. There was a complete right facial paralysis, and the temporal and pre-auricular regions were extremely tender to touch. The patient had to lie still and not move from side to side or sit up, because any movement produced a very disturbing dizziness. He said that the dizziness, however, was not nearly so severe as when his ear "broke" and that the hearing had become somewhat better. The eyes reacted normally to light and accommodation and the pupils were equal and regular. The Wassermann test was negative. Two days later the pain had decreased and he was hearing somewhat better. The eruptions on the face were healing quite rapidly. Eleven days later the vesicles were almost entirely healed, and he could hear conversational voice at eight feet in the right ear. The facial paralysis seemed to be slightly less. The right ear canal and drum membrane were practically normal. Vestibular tests showed no reaction in the right semicircular canal with the head in any position. The douching was done with water at 68 degrees Fahrenheit. The patient was discharged from the hospital October 26th, twenty-four days after his entrance. At that time there was noticeable improvement in the facial paralysis and the hearing had improved. The skin of the right side of the face was clear and the dizziness had entirely subsided.

I should add that the diagnosis on entering the hospital was quite uncertain. Dr. A. H. Miller, senior resident, in the ear, nose and throat department, Dr. Cyril Francis and Dr. Fitzgibbon of the medical resident staff began to study the literature and suspected that it was a case of Ramsey Hunt ganglion syndrome. This diagnosis was confirmed by Dr. J. M. Nielson and Dr. Samuel Ingham, attending neurologists of the hospital. I was told about the case and when I examined the patient at the hospital it seemed quite clear that it was another one of these rare cases, where the signs and symptoms were due to inflammation of the cranial ganglia. In this case the ganglion of the fifth nerve was involved, and also the geniculate ganglion of the seventh nerve, which latter ganglion was not involved in my first case.

I wish to thank Dr. Frank Detling, chief of the Department of Otolaryngology at the General Hospital, for permission to report the hospital findings in this case.

My last examination of this patient was made on November 21, 1934, at which time his facial paralyis had almost subsided and the eruptions had disappeared, but small scars were still present in the pre-auricular region. The hearing had become almost normal.

The vestibular tests at the time of my last examination were as follows: No past pointing with either arm. No spontaneous nystagmus. Douching the right ear canal with water 66 degrees showed no nystagmus after six minutes and no past-pointing. The patient was made slightly dizzy after three minutes' douching. Douching the left ear produced slight dizziness at a minute and a half, but no nystagmus or past-pointing. The falling reaction was normal on turning five times in ten seconds to the right, and also when turning five times in ten seconds to the left. The patient said he was never dizzy except when looking quickly up or down and particularly when stooping over. His hearing tests—equal in the two ears—showed W. V. 12 feet plus, which the patient said was as good as he had heard for several years. The Weber was not lateralized. Bone conduction for C = 256 fork was equal in the two sides; Rinne was plus in each ear; the lower tone, C = 64 fork, was normal in each ear; the uuper tone, C = 2046 fork, was especially good for his age,—minus ten seconds in each ear.

COMMENTS.

It is apparent from my study of the literature that these cases are extremely rare. Hunt states, in his original article in 1907 (Journal of Nervous and Mental Diseases), that at the Manhattan Eye and Ear Hospital covering a period of ten years and over 47,000 cases, the diagnosis of herpes zoster of the auricle was made twice. In the Brooklyn Eye and Ear Hospital, with a total of 15,000 cases in five years, the diagnosis was made once; in the New York Eye and Ear Infirmary, with an average of 10,000 patients yearly, this diagnosis was recorded only six times. At the Massachusetts Eye and Ear Infirmary in ten years, covering 65,000 patients, this diagnosis was made thirty-three times.

The sudden onset of pain in the ear, bloody serum, and especially when accompanied by facial paralysis, naturally has made observers believe there was an acute middle ear infection. It is, therefore, not surprising that in some cases the mastoid has been opened

on account of an incorrect diagnosis. Kaufmann reports a case in which the diagnosis of acute mastoiditis was made and a mastoid operation performed. Halphen also reported a similar case—acute mastoiditis and a possible thrombosis of the lateral sinus, due to the grave symptoms of mastoid pain, inflamed drum membrane, swelling of the neck and facial paralysis. A correct diagnosis of acute hemorrhagic inflammation of the ganglia or ganglia root of one or more cranial nerves cannot, of course, be absolutely proven without an autopsy. It is obvious that these patients rarely die during the attack, so an autopsy to prove the diagnosis is wanting. However, by analogy the correct diagnosis should be made, as the knowledge of herpes zoster, commonly known as shingles, has been proven to be an acute hemorrhagic inflammation of the posterior root ganglia of the spinal cord. In 1861, von Barensprung, in a case of "shingles" involving the skin of the chest, reported the first autopsy, clearly demonstrating the involvement of the posterior root ganglia of the spinal cord, and stamped shingles as a ganglion disease and not a primary terminal neuritis involving the skin of the chest. In ophthalmic literature cases of herpes zoster involving the ophthalmic division of the fifth nerve have occurred and had been, and still are sometimes, mistaken for inflammation of the nerve terminals in the skin of the supra-orbital region; but in 1871 Wyss fortunately was able to get an autopsy in a case of this kind in which death occurred from other causes and was painstaking enough to examine the semilunar ganglion of the fifth nerve, and found a hemorrhagic inflammation of the ganglion similar to that found previously by von Barensprung in the posterior root ganglia of the spinal cord in his case of shingles of the chest. Sattler, in 1875, confirmed these autopsy reports in an identical case. Head and Campbell, in 1900, gave us the results of their clinical and pathologic investigation of herpes zoster in twenty-one autopsies, and to them is given the credit for clarifying the whole subject of pure ganglion involvement. J. Ramsey Hunt, previously quoted, in 1907, was the first to place on record herpes zoster cases involving our specialty.

In reporting these cases I wish to call attention to the possibility of mistaking herpes zoster oticus for an acute middle ear infection; also to the necessity of being on the lookout for a possible death, from other causes, during an attack of herpes zoster oticus, in order that an autopsy can be obtained and sections made of the cranial nerve ganglia proving that the primary lesion is in the ganglia or ganglia roots.

1136 West 6th St.

BIBLIOGRAPHY.

Hunt, J. Ramsey: "On Herpetic Inflammations of the Geniculate Ganglion. A New Syndrome and Its Complications." J. Nervous and Mental Diseases, 34: 73-96 (Feb.), 1907.

Buckingham, T. W.: "Herpes Zoster Oticus. Report of a Case with Facial Paralysis." Arch. of Otolaryng., 13:59-62 (Jan.), 1931.

Goodell, William: "Herpes Zoster Oticus. Report of Two Cases." Arch. of Otolaryng., 14:822-825 (Dec.), 1931.

Stewart, J. P.: "Herpes Zoster Oticus." J. Laryngology and Otology, 42:665-673 (Oct.), 1927.

Sears, Wm. Hardin: "Herpes Zoster Oticus." ANNALS OF OTOLOGY, RHINOLOGY AND LARYNGOLOGY, 36:361-384 (June), 1927.

Dennis, Frank L.: "Herpes Zoster Oticus. A Case with Involvement of the Fifth, Seventh, Eighth and Ninth Cranial Nerves and with a Complete Vestibular Examination." Laryngoscope, 35:665-674 (Sept.), 1925.

Hunt, J. Ramsey: "The Symptom Complex of the Acute Posterior Poliomyelitis of the Geniculate, Auditory, Glossopharyngeal and Pneumogastric Ganglia." Arch. of Int. Med., 5:631-675 (June), 1910.

Vail, Derrick T.: "Herpes Zoster Auris." Trans. Am. Laryng., Rhino. and Oto. Soc., 12:273-282, 1906.

Fenton, Ralph A.: "Diagnostic Factors Concerning Herpes Zoster Oticus." J. A. M. A., Vol. 103, No. 7, 1934.

Book Received.

Corrective Rhinoplastic Surgery.

Joseph Safian, M. D., Attending Plastic Surgeon, Sydenham, Beth David and Jewish Memorial Hospitals, New York City. Cloth. Octavo of 218 pages with 242 illustrations. New York: Paul B. Hoeber: 1935. Price $9.00.

This monograph is comprehensive and practical. It treats of nasal deformities under seven general heads, describes the mechanical and surgical problems in each case, and outlines the operation indicated. There are numerous diagrams to guide the beginner.

The author describes an ingenious device, made of celluloid and laid upon a photograph, for determining the angle, the nature and the degree of departure from the normal. Unfortunately he calls it a "photometer," which is confusing, as the device is not in any sense used for measuring light intensity.

Typography and binding are of Hoeber's usual high standard.

Notices.

Casselberry Prize Fund.

The sum of $500.00 having accrued from the Casselberry Fund for encouraging advancement in the art and science of Laryngology and Rhinology, said sum is now available, in part or as a whole, for a prize award, decoration, or the expense for original investigation or research in the domains mentioned above. Theses or reports of work must be in the hands of the Secretary, Dr. James A. Babbitt, 1912 Spruce Street, Philadelphia, before February 1st of any given year.

Mississippi Valley Medical Society

The first annual meeting of the newly formed Mississippi Valley Medical Society will be held at the Lincoln-Douglas Hotel, Quincy, Illinois, on October 2, 3, 4, 1935. A most practical program of intensive postgraduate instruction by eminent clinicians has been arranged. A preliminary program may be obtained from the Secretary, Harold Swanberg, M. D., 211-224 W. C. U. Building, Quincy, Illinois.

The American Academy of Ophthalmology and Otolaryngology

The next annual meeting of the American Academy of Ophthalmology and Otolaryngology will constitute a celebration of the Silver Anniversary of this body in its present form. The meeting will be held in Cincinnati, Ohio, from September 14th to 20th.

The American Board of Otolaryngology

An examination was held in New York City, June 8, 1935. One hundred and nine candidates were examined, of which number eighty-five were certified and twenty-four were conditioned or failed.

The Board will hold an examination in Cincinnati, Ohio, September 14, 1935, prior to the meeting of the American Academy of Ophthalmology and Otolaryngology. Prospective applicants for certificate should address the Secretary, Dr. W. P. Wherry, 1500 Medical Arts Building, Omaha, Nebraska, for application blanks.

W. P. Wherry, M. D., Secretary-Treasurer.

H. P. Mosher, M. D., President.

The Biologic Photographic Association.

The fifth convention of The Biological Photographic Association will be held in the south assembly room on the third floor of Hotel Stevens, Chicago, September 12th, 13th and 14th.

The program, which includes several eminent speakers, should be of especial interest to medical authors.

The Secretary is Anne Shiras, University Office, Magee Hospital, Pittsburgh, Pa.

The French counterpart of this association, the "Association pour la Documentation Photographique et Cinématographique Dans les Sciences, will meet in Paris, October 4th to 11th, at the Musée Pédagogique de l'Etat. Foreigners are invited to attend and to exhibit.

Society of Plastic and Reconstructive Surgery.

The fourth annual meeting of the Society of Plastic and Reconstructive Surgery will be held at the Hotel Statler, Detroit, Michigan, October 18th and 19th, 1935. Members of the medical profession are invited to attend.

Arthur Palmer, M. D., General Secretary.

Abstracts of Current Articles.

LARYNX.

Anatomical Topographical Notes on the Superior Laryngeal Nerve (Rilievi anatomo-topografici sul nervo laringeo superiore).

Ferreri, G. (Perugia), Valsalva, 10:737-753 (October), 1934.

A worth while, up-to-date article on the superior laryngeal nerve, containing four histologic and three anatomic photographs and a measurement table.

The author takes up again the study of this nerve from the anatomic, topographic and histologic point of view; all his researches were conducted on cadavers.

He describes minutely anatomic details of the superior laryngeal, especially of its internal branch (thyrohyoid), which is of particular interest to the laryngologist.

Then he concludes by furnishing practical data in rendering much simpler the technics for anesthetization and resection of the superior laryngeal which, according to the author, are rather difficult procedures to accomplish well.

SCIARRETTA.

EAR.

The Ear and Cranial Trauma.

Murphy, Albert B. (Everett, Wash.), Arch. of Otolaryng., 21:686, (June), 1935.

A group of 176 cases of cranial trauma has been studied. The following is a substitute classification that seems to include all types:

1. Cases of fracture involving the external canal only.

2. Cases of fracture involving the middle or inner ear.

3. Cases of patients with symptoms referable to the ear without apparent fracture.

With this classification there is still considerable overlapping, but it seems unavoidable. Fifteen cases have been observed in which the fracture involved the external canal only, demonstrating that there can be bleeding from the ear without involvement of the structure of the middle or inner ear. The susceptibility of patients suffer-

ing from cranial trauma to ear trauma has not been sufficiently emphasized. The preponderance of symptoms that lend themselves to exaggeration was not greater in the group having compensation than in those not receiving compensation. One should be conservative in interpreting the neuro-otologic findings in terms of percentage loss of function.

TOBEY.

Association of Toxic Deafness With Toxic Amblyopia Due to Tobacco and Alcohol.

Carroll, Frank D. (New York), and Ireland, Percy E. (Toronto), Arch. of Otolaryng., 21:459 (April), 1935.

Toxic deafness frequently accompanies toxic amblyopia associated with the use of tobacco and alcohol. A large percentage of the patients showed an island defect at a frequency of 4,096 vibrations. This was not observed in the control group and is quite comparable to the island defect found in the visual fields of patients with amblyopia. There is a general reduction in the perception of high tones and a lowering of the bone-conduction time. In comparison with a control group of the same age this is shown to be due in part to toxic causes rather than to the usual senile defects. There is probably an improvement in hearing function accompanying the improvement in vision on abstinence.

TOBEY.

Relations Between Experimental Rickets and Otosclerosis (Sui rapporti tra rachitismo sperimentale e otospongiosi).

Aprile, V. (Roma), Valsalva, 10:649-462 (September), 1934.

The author reviews superficially the pathology and the most accepted etiologic theories of otosclerosis. Reports his experiments and results obtained after placing rats on a special rachitogenic diet (formula of Shennan and Pappenheim) and also presents some microphotographs of the temporal bones of these animals.

He finally describes the histologic changes in the petrosa, especially in the labyrinthine capsule, which are invariably located at the anterior margins of the oval window.

The sequences of pathologic changes are: venous stasis, followed by osseous decalcification and active proliferation of cartilaginous zones with transformation into osteoid substance. These changes, although not characteristic, are very similar to those found in the human otosclerosis.

SCIARRETTA.

Pathogenesis of Professional Deafness in Aviators. (La pathogenie de surdité professional chez les aviateurs.)

Aubriot, P. (Nancy), O., R., L. Internat., 23:65 (Feb.), 1935.

In those constantly exposed to sound traumatism, the tympanum and middle ear apparatus act as defenders of the internal ear. When slight scarring or tubo-tympanic involvement exist, modifying the defensive powers of the drum membrane and ossicular chain, although hearing may not yet be affected, exposure to constant motor noise is much more likely to bring about rapid deterioration of function than in persons with previously normal middle ear structures.

Very strict tubo-tympanic examination of prospective pilots is therefore desirable, excluding those with lesions of the middle ear of no account in ordinary life, yet rendering the internal ear vulnerable to the violent trauma of long continued mechanical noise.

FENTON.

Architectural Details of the Zygomatic Process—Their Clinical Significance. (Particularités architecturales de l'apophyse sygomatique de l'os temporal et leur signification clinique.)

Davidoff, I. E. (Charkov), Rev. de Lar., Otol., Rhin., 56:253 (March), 1935.

This very complete anatomical study of many temporal bones and numerous clinical cases discloses the following facts: Pneumatization of the root of the zygoma and the squama above the temporal line was found in 44.6 per cent, and downward into the antero-inferior part of the squama in 36 per cent of the cases reported. No pneumatization of the zygoma itself or of the anterior auricular tubercle was found. If the mastoid was pneumatic, Davidoff found zygomatic and squamous pneumatization above the temporal line in 94 per cent; with mixed mastoid cells, 17.2 per cent; but there was no such pneumatization with the diploetic or sclerosed mastoid. Such pneumatization occurs at the expense of the mastoid antrum, and the zygomatic cells are lined by a thin mucosa. Pneumatization of the lower edge of the squama begins in the first months of life.

The author distinguishes three clinical forms: squamo-mastoiditis and zygomatic mastoiditis; late zygomatic involvement; and primary or isolated zygomatic suppuration. These are best exposed by a horizontal incision along the lower zygomatic border, prolonging the mastoid incision forward.

This monograph of 75 pages is well illustrated and has a good bibliography.

FENTON.

MISCELLANEOUS.

Evipan as a General Anesthetic in Otolaryngology (L'anesthésie générale à l'évipan-sodique en oto-rhino-laryngologie).

Terracol, J., and Balmès, J. (Montpellier). O. R. L. Internat., 19:5 (Jan.), 1935.

Professor Terracol has made a careful study of the dangers and limitations of evipan, pointing out the necessity of careful preliminary study, of very slow intravenous injection—1 cc. per minute—and contraindications such as grave sepsis, cardiorenal insufficiency, deep sepsis of the neck or tongue, etc. Since evipan does not abolish the pharyngolaryngeal reflexes, fatal spasm of the glottis may occur.

Local anesthesia is preferable for tonsil, sinus and septum surgery; but evipan is useful in dental extractions during acute inflammation, or osteomyelitis of the mandible, controlling trismus and avoiding the dangers of local anesthesia in such cases.

Operations on the ear and mastoid are well managed under evipan, but excitement while waking up may cause annoyance. It is never to be used for minor surgery done in one's office, and must still be regarded as experimental in otolaryngology.

FENTON.

Infections of the Neck.

Havens, Fred Z. (Rochester, Minn.), Arch. of Otolaryng., 21:536 (May), 1935.

These have been divided into five classifications. First, there are acute suppurative conditions in the neck secondary to infections elsewhere. Many of these originate in some infection about the mouth, although they may come from infection about the scalp or face and occasionally from more distant points. They may develop by metastasis or by direct extension. The second type is known as woody or ligenous phlegmon, a condition which is probably secondary to infection elsewhere and in which there is marked induration but in which suppuration never occurs. In the third group are infections due to certain specific causes, and in this group are tuberculosis, syphilis, actinomycosis, blastomycosis and a rare condition, tularemia. The fourth group consists of infected cysts and infected tumors of various kinds, such as cystic hygroma, lymphangioma and degenerated malignant lymph nodes. The fifth group includes thyroiditis, which may be of the acute suppurative or nonsuppurative type. Both types are rather rare, and the nonsuppurative type often is not suspected until it is encountered surgically.

It is better to treat the acute suppurative conditions of the neck conservatively. The results in this series of 103 cases, with only one fatality, demonstrate the value of this. It is not good surgical judgment to open a wide wound in the neck

to search for pus in the presence of what usually is a virulent infection. In acute suppurative conditions in the neck, the pus does not burrow along the fascial planes as frequently as the anatomist would have one believe. Instead, in the vast majority of cases, nature builds a barrier around the abscess and forces it to burrow toward the surface. Experience would lead one to believe that jugular thrombosis is an infrequent complication of acute suppurative conditions in the neck. The possibility of its occurrence should always be borne in mind, however, and there should be little difficulty in recognizing it, so that appropriate treatment can be instituted.

TOBEY.

Tracheobronchial Aspiration of Buccopharyngeal Secretion During Ether Anesthesia: Immediate Postoperative Bronchoscopic Study of Twenty-one Patients.

Lowenthall, Gerson (Cincinnati), Arch. of Otolaryng., 21:561 (May), 1935.

The literature dealing with cases of postoperative pulmonary suppurative complications, especially of the aspiratory type, ocurring in animals and in human beings, was reviewed from the experimental, clinical and pathologic points of view. A bronchoscopic postoperative study was made in human beings in whom the pharyngeal content was not artificially increased by blood, and aspiration was not made easier by manipulation of the tongue (as tonsillectomy). The data analyzed led to the following conclusions:

(a) In operations performed with the patients under ether anesthesia on parts which do not drain into the pharynx, with the patient in the supine (horizontal) position, aspiration of pharyngeal content into the tracheobronchial tree occurred in 76 per cent of the small series of cases studied.

(b) It was shown that either no aspiration occurs in a small proportion of cases (24 per cent), or aspiration takes place in a large proportion (76 per cent); when it does occur it is likely to involve the entire bronchoscopically visible portion of the tracheobronchial tree.

(c) There is no significant difference between the percentage of cases of aspiration in etherized patients with operations on the upper respiratory passages or pharynx (from 62 to 79 per cent) in the cases obtained from the literature and that in the cases in this series (76 per cent).

(d) Aspiration by etherized patients in this series and in the various series reported in the literature is twice as frequent as in patients undergoing tonsillectomy under local anesthesia.

Aspiration is important as an etiologic factor in postoperative pneumonopathy, even in cases in which the operation is not on the pharynx, mouth or nose. Frequent or continuous suction is suggested as a means of decreasing the amount of pharyngeal content subject to aspiration. The hygienic condition of the mouth, nose and throat is an important factor, since on this depends the infectivity of aspirated material.

TOBEY.